SILICON CHIP

The BEST DIY Projects!

OCTOBER 2017
ISSN 1030-2662
10
9 771030 266001
PP255003/01272
$9.95* NZ$12.90 INC GST

THE BEST Frequency Meter published ANYWHERE in THE WORLD!

- 0.01Hz – 6+GHz Range
- 5-in Colour Touchscreen
- High Sensitivity
- High Accuracy
- 10-digit Resolution
- GPS Reference Option

And THE BEST part? You BUILD IT YOURSELF and $AVE!

A one-hour SILICON CHIP project - but with all the info you need!

KELVIN the CLEVER CRICKET

He's so smart he can even tell you the temperature!

Australia joins the exclusive space club, launching its first satellite . . . way back in 1967!

Jaycar Electronics
Better, More Technical

duinotech
PROJECT OF THE MONTH

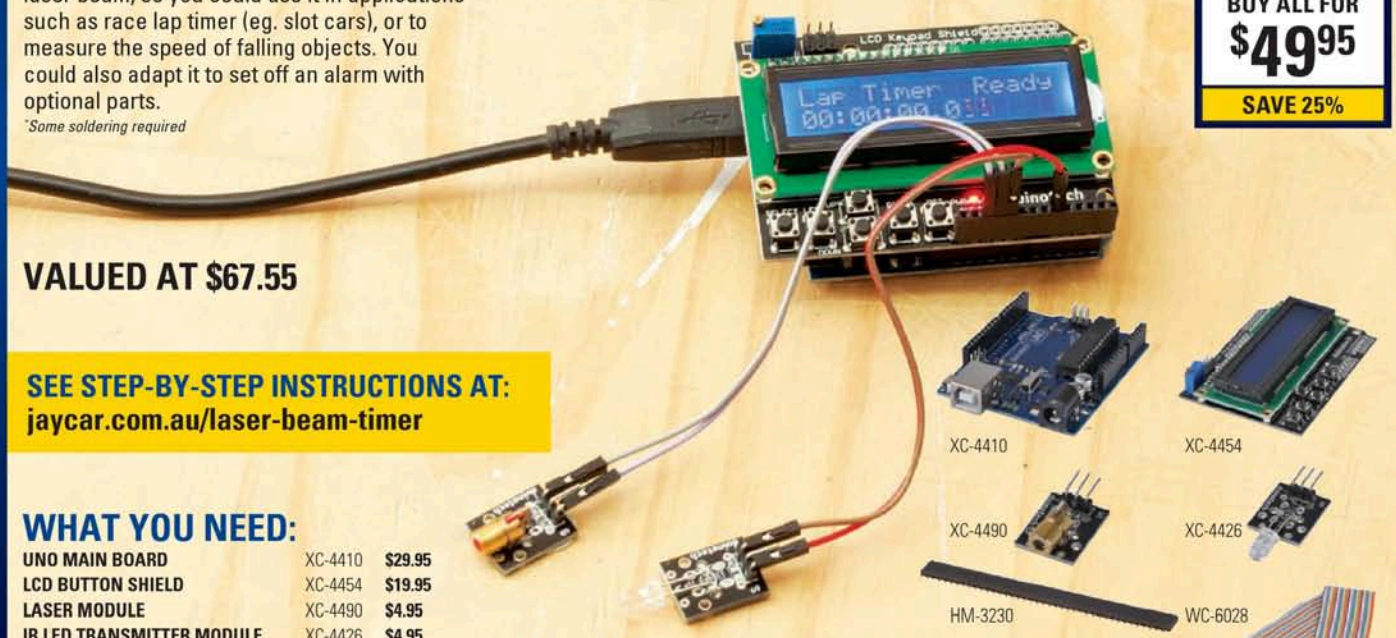
Our very own specialists are developing fun and challenging Arduino®-compatible projects for you to build every month, with special prices exclusive to Nerd Perks Club Members.

LASER BEAM TIMER USING ARDUINO®

This versatile timer project is triggered by a laser beam, so you could use it in applications such as race lap timer (eg. slot cars), or to measure the speed of falling objects. You could also adapt it to set off an alarm with optional parts.

*Some soldering required

NERD PERKS CLUB OFFER
BUY ALL FOR $49.95
SAVE 25%



VALUED AT $67.55

SEE STEP-BY-STEP INSTRUCTIONS AT:
jaycar.com.au/laser-beam-timer

XC-4410

XC-4454

XC-4490

XC-4426

HM-3230

WC-6028

WHAT YOU NEED:

UNO MAIN BOARD	XC-4410	**$29.95**
LCD BUTTON SHIELD	XC-4454	**$19.95**
LASER MODULE	XC-4490	**$4.95**
IR LED TRANSMITTER MODULE	XC-4426	**$4.95**
FEMALE HEADER STRIP	HM-3230	**$1.80**
JUMPER LEADS	WC-6028	**$5.95**

SEE OTHER PROJECTS AT: www.jaycar.com.au/arduino

ADD SOUND ALERT

ACTIVE BUZZER MODULE XC-4424

The easy way to add sound to your project. Hook up a digital pin and ground, and use the tone() function to get your Arduino® beeping.

$3.95

ADD MORE IO's

DUINOTECH MEGA

XC-4420

Our most powerful Arduino® compatible board. Boasting more IO pins, more memory, more PWM outputs, more analogue inputs and more serial ports.

- 256kb program memory
- ATMega2560 Microcontroller
- 108(W) x 53(L) x 15(H)mm

$49.95

ACTIVATE A DEVICE

5V RELAY BOARD

XC-4419

Available in one, four and eight channel versions, these modules can switch up to 10A per channel.

- Status LEDs show channel status
- Screw terminals for easy connection to relay contact.
- SPDT Relays

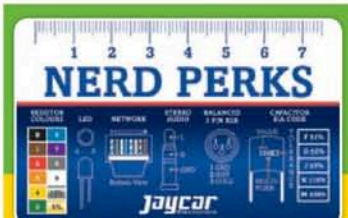
1 CHANNEL XC-4419 **$5.45**
4 CHANNEL XC-4440 **$12.95**
8 CHANNEL XC-4418 **$19.95**

FROM $5.45

NERD PERKS CLUB MEMBERS RECEIVE:

20% OFF
XLR & CANNON CONNECTORS*

*INCLUDES AMPHENOL XLR PLUGS & SOCKETS, MINI XLR PLUGS & SOCKETS



EARN A POINT FOR EVERY DOLLAR SPENT AT ANY JAYCAR COMPANY STORE* & BE REWARDED WITH A $25 JAYCOINS GIFT CARD ONCE YOU REACH 500 POINTS!

*Conditions apply. See website for T&Cs

REGISTER ONLINE TODAY BY VISITING:
www.jaycar.com.au/nerdperks

Contents

Vol.30, No.10; October 2017

SILICON CHIP

www.siliconchip.com.au

Features & Reviews

13 WRESAT: Australia's first satellite – 50 years ago!
Very few people remember that Australia was just the seventh country to launch its own satellite – on November 29, 1967. This technical triumph could have been the start of a productive space industry – by Dr David Maddison

23 Three of our miniature satellites have gone missing . . .
Three tiny Cubesats, built by Australian students and deployed from the International Space Station earlier this year, simply disappeared. How do you search for missing satellites 400km away in space? – by Ross Tester

36 El Cheapo Modules Part 10: GPS receivers
Ten years ago, GPS modules cost $170 each (and more). Now they cost around 1/10th of that and they offer significantly better performance! And they're not just used for location – they make superb time references too – by Jim Rowe

80 Reduce your hot-water thermostat and save $$$$
Electric hot water is one of the biggest energy costs in most homes. Want to save money while making your home safer for children and older people? Simply reduce the hot-water heater thermostat setting – by Leo Simpson

Constructional Projects

26 0.01Hz - 6GHz+ Touchscreen Frequency Meter, Part 1
It's the best Frequency Meter you've ever seen! With performance up to around 7GHz, a 5-inch colour touchscreen, 10-digit resolution and high sensitivity, you'll want one of these on your workbench – by Nicholas Vinen

42 One hour project: Kelvin – the very clever cricket
Would you believe Kelvin can actually read the temperature – and then tell you what it is? His chirps sound so much like a real cricket your friends will be looking around for one! – by John Clarke

66 3-way Active Crossover for speakers, Part 2
Introduced last month, this Active Crossover is one for the true Audiophile. Now we go through the fun of building it and setting it up to suit your audio system – by John Clarke

76 Deluxe eFuse, Part 3: using it!
We've already described the circuit details, how it works and what it will do for you, here's the detailed information on how to operate the unit with some screen grabs showing its various functions – by Nicholas Vinen

Your Favourite Columns

58 Serviceman's Log
Old-fashioned appliance repairs are still worthwhile – by Dave Thompson

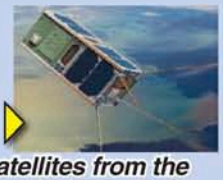
82 Circuit Notebook
(1) Modifications to mains power supply for battery valve radio sets
(2) Recalibrating the oscillator in a PIC12F675 or PIC12F629
(3) Bipolar transistor tester, Mk II
(4) Using a 5-inch touchscreen with the Micromite Plus Explore 64

88 Vintage Radio
HMV 1955 Portable Model 12-11 – by Associate Professor Graham Parslow

Everything Else!

2 Editorial Viewpoint
4 Mailbag – Your Feedback
94 SILICON CHIP Online Shop
96 Ask SILICON CHIP
103 Market Centre
104 Advertising Index
104 Notes and Errata

Australia joined a very exclusive club, launching its first satellite – WRESAT – way back in 1967 – Page 13



Fifty years later, Australians launched three shoe-box-sized satellites from the International Space Station – but where did they go? – Page 23

Wow! Wow! Wow! What a performer! Our new touch-screen frequency counter offers performance approaching 7GHz – and down to 0.01Hz – Page 26

Tiny GPS Modules are now SO cheap – and you can do so much more with them than tell you where you are. – Page 36

Kelvin is one clever Cricket! He senses the temperature and then chirps the number of degrees to you (in Cricket code) as well as flashing his eyes. You can build Kelvin in about one hour! – Page 42

Putting together and setting up our sensational 3-way Active Crossover for Speakers – Page 66

Find us on Facebook

www.facebook.com/siliconchipmagazine

SILICON CHIP
www.siliconchip.com.au

Publisher
Leo Simpson, B.Bus., FAICD

Editor
Nicholas Vinen

Technical Editor
John Clarke, B.E.(Elec.)

Technical Staff
Ross Tester
Jim Rowe, B.A., B.Sc
Bao Smith, B.Sc

Photography
Ross Tester

Reader Services
Ann Morris

Advertising Enquiries
Glyn Smith
Phone (02) 9939 3295
Mobile 0431 792 293
glyn@siliconchip.com.au

Regular Contributors
Dave Thompson
David Maddison B.App.Sc. (Hons 1), PhD, Grad.Dip.Entr.Innov.
Geoff Graham
Associate Professor Graham Parslow
Ian Batty

Cartoonist
Brendan Akhurst

SILICON CHIP is published 12 times a year by Silicon Chip Publications Pty Ltd. ACN 003 205 490. ABN 49 003 205 490. All material is copyright ©. No part of this publication may be reproduced without the written consent of the publisher.

Subscription rates: $105.00 per year in Australia. For overseas rates, see www.siliconchip.com.au/subscriptions

Editorial office:

Unit 1 (up ramp), 234 Harbord Rd, Brookvale, NSW 2100.

Postal address: PO Box 139, Collaroy Beach, NSW 2097.

Phone (02) 9939 3295.

E-mail: silicon@siliconchip.com.au

Printing and Distribution:
bluestar
Derby Street, Silverwater, NSW 2148.

ISSN 1030-2662
Recommended & maximum price only.

Editorial Viewpoint

Let's be realistic about an Australian space industry

On page 13 of this issue we bring you the story of WRESAT: Australia's first satellite, launched in 1969. The author, Dr David Maddison, laments that this could have been the start of an Australian space industry. But no!

Fifty years later, the Australian Federal Government has announced a review into our domestic space industry capabilities. Announced on 13th July this year, it is expected to be completed by end of March 2018.

In support of this, at least one Australian space-based start-up company has "urged the government to commit to a new space agency", according to an article in The Australian ("*Red tape holding back our rockets*", 25th August 2017). But just how feasible is an Australian Space Agency?

If red tape is holding back our rockets, would increasing the government's involvement necessarily improve the situation? Consider that NASA was the world's premier space agency for many decades but now they are a shadow of their former selves – thanks mainly to government.

Of the 62 resupply missions to the International Space Station this decade, 32 were carried out using Russian rockets and spacecraft, four by the EU and five by Japan. Of the remaining 21 flights which used US-built rockets, nearly two-thirds (13) were Falcon 9 rockets built by private firm SpaceX.

NASA used to drive US space innovation but now it's companies like SpaceX who are driving the technology.

There is probably a reason for this; governments are not good at running large, complex engineering operations. Most would agree that rolling out a broadband network is not nearly as complex as a space program and yet Australia seems to be incapable of doing that in a smooth manner within any kind of sensible budget.

An Australian government-run space agency is likely to be a similar morass.

Let's be realistic, Australia's population is too small and we're too remote to support a huge space industry. After all, we couldn't even support an automotive industry without massive cash handouts.

But we do have some unique attributes which could make us a valuable and lucrative part of the global space industry. We have some great launch facilities, including Woomera, and a lot of empty space to play with. It would definitely make sense for Woomera to be shared between the Department of Defence and industry and the DoD could even benefit from commercially built and maintained launch facilities. Defence would also benefit from the improvement in local expertise that a commercial space industry would bring.

We also have a lot of great engineers and scientists, some of whom are already involved in designing and building satellites and other space hardware. We should definitely be open to more collaboration but it would probably be a waste of money to establish our own dedicated space program.

Remember also that most countries with a successful government-run space program (and thus the ability to launch satellites) have achieved it as the side-effect of a military rocket program.

Despite the recent alarming events in North Korea, I don't think we're ever going to develop any long-range missiles. If we are going to launch satellites, it will probably be on top of foreign-built rockets.

So, given the fact that the global space industry is increasingly being privatised and also that large companies are increasingly becoming global operations, with design and manufacturing spread out over the planet, the Australian space industry is unlikely to rival that of countries like the USA.

But we should still participate as we stand to benefit greatly from doing so.

Nicholas Vinen

360° Innovation COVERAGE

FREE SHIPPING ON QUALIFIED ORDERS*

AUSTRALIA
DIGIKEY.COM.AU
1800 285 719

NEW ZEALAND
DIGIKEY.CO.NZ
800 449 837

Digi-Key® ELECTRONICS

6 MILLION PARTS ONLINE | 650+ INDUSTRY-LEADING SUPPLIERS | 100% AUTHORIZED DISTRIBUTOR

*Australia: A shipping charge of $24.00 AUD will be billed on all orders of less than $60.00 AUD. A shipping charge of $20.00 USD will be billed on all orders of less than $50.00 USD. All orders are shipped via UPS, Federal Express, or DHL for delivery within 3-4 days (dependent on final destination). No handling fees. All prices are in Australian dollar or United States dollar. **New Zealand:** A shipping charge of $26.00 (NZD) will be billed on all orders of less than $66.00 (NZD). A shipping charge of $20.00 USD will be billed on all orders of less than $50.00 USD. All orders are shipped via UPS for delivery within 3-4 days (dependent on final destination). All prices are in New Zealand dollar or United States dollar. Digi-Key is an authorized distributor for all supplier partners. New product added daily. Digi-Key and Digi-Key Electronics are registered trademarks of Digi-Key Electronics in the U.S. and other countries. © 2017 Digi-Key Electronics, 701 Brooks Ave. South, Thief River Falls, MN 56701, USA

eda MEMBER ecsn member CEDA

MAILBAG – your feedback

Letters and emails should contain complete name, address and daytime phone number. Letters to the Editor are submitted on the condition that Silicon Chip Publications Pty Ltd may edit and has the right to reproduce in electronic form and communicate these letters. This also applies to submissions to "Ask SILICON CHIP", "Circuit Notebook" and "Serviceman".

Microbridge serial interface connector pinout is correct

I read the comment from Mike Flor in the Mailbag section of the July 2017 issue regarding the pinout of the serial connector on the Microbridge (May 2017; www.siliconchip.com.au/Article/10648).

His comment and your response both miss the point; the TX and RX pins have been purposefully swapped compared to the BackPack boards.

When interfacing two serial devices, the TX pin of one goes to the RX of the other and vice versa.

So the Microbridge can be plugged directly into the console connector of the LCD BackPack and it will work fine. I designed it that way!

Geoff Graham,
Perth, WA.

Praise for analog circuitry

In this day and age of all things digital in electronics, there's one area that still fascinates this electronics enthusiast when it comes to technology. That is the confluence of the human ear and electronics.

The war was fought; solid-state outdid all analog devices and then complete digital systems outdid their analog counterparts... or did they?

I've been amazed recently at the abundance of new valve amplifiers and analog audio technology appearing on the market in the last couple of years. (Not to mention the rise of the turntable and vinyl records again).

It has always been there in the background (so to speak) but when I take a wander into my local hifi dealer and they're recommending I go for a valve style pre-amp for example, surely this marketing amidst a multitude of other very good reasons has got to show that analog is clearly alive and well.

Today I was looking through the pages of a magazine I purchased purely because it had a nice picture of an Australian manufactured aircraft. This was the "Jindivik". This aircraft was an unmanned aerial vehicle (UAV).

Well, UAV's are the future of Aviation and the next big step so that would be a good article to include. But here's the surprise: this issue is dated June 1969 and is *Electronics Australia*. Australia has actually been looking into this technology for a very long time now.

Back to analog electronics and my reason for this letter: inside that magazine, I found a great circuit for a Theremin. I have already built one using op amps with great success but if there's one thing I really love in the electronics world, it's simple circuits that can achieve the exact same results.

I refer to a tasty little circuit on page 98 that most enthusiasts should be able to build simply on a good old protoboard, requiring only seven transistors and one FET. It should be possible to do this in one day.

And who wrote the article and even provided a nice enclosure plan for the circuit? The now legendary Leo Simpson.

So thank you, Mr Simpson, for a great circuit which you actually designed around 48 years ago. It's just as valid for music creators and sound effects enthusiasts like myself today as it was first designed.

By the look things, it will remain so for the future as well. Perhaps an updated valve-style version for a new SILICON CHIP article might be worth considering!

Sean Curtin,
via email.

Editor's response: we are considering updating that Theremin design to use commonly available parts and producing a PCB for it.

Regarding the resurgence of valve and vinyl equipment, there are few

Flash support will end soon, regardless of the consequences

I read your reply to Terry Ives' letter in the August 2017 mailbag regarding Flash and the SILICON CHIP website, and I couldn't help wonder if your stance has changed since Adobe's big announcement (after the issue went to print), that Flash support would be discontinued in 2020.

I can completely understand your aversion to re-engineering your production processes and website code around a new format but you may not have much choice. See: http://siliconchip.com.au/l/aag3

What makes this even more serious from a content-creator's point of view, is that the major browser developers have all banded together to ensure that Flash Player will no longer function after 2020 either.

So it's not just a case of ceasing development, but a case that existing content will stop working then too! See this URL: http://siliconchip.com.au/l/aag2

Content developers are going to be forced to adopt the newer HTML5 and WebGL technologies or face their sites not working any more.

Sticking with only Flash means it all breaks in 2020. I would expect that well before then Adobe will have added the HTML5 export function to their InDesign product.

I hope this info helps plan your successful migration strategy well in advance.

Pete Mundy,
Nelson, NZ.

Response: it seems unlikely that there will be good HTML5-based alternatives to Flash by 2020 given that they are still lacking as of late 2017. After all, it's less than three years away. We expect there will still be ways to view Flash content after 2020.

However, we cannot expect our readers to jump through hoops to view the online issue. So it seems likely that we will ultimately need to come up with a completely different method for producing and/or distributing online issues.

objective reasons to prefer these over solid state analog electronics and CDs.

Solid state amplifiers do a much better job of reproducing the original audio and vinyl records suffer from many problems that CDs don't, including stylus pinch effects and inner groove distortion, wow & flutter, rumble, dust, scratches, fungal growth, etc.

Perhaps the resurgence of valves and vinyl is a justifiable, if misguided, backlash against the decidedly poor sound quality produced by MP3s and other digitally compressed files.

It's certainly hard to consider anything that has been compressed in a lossy manner as "hifi". Whether or not it makes sense, valves and vinyl do seem to be making a significant comeback.

Anyone who wants the best audio quality should build one of our Ultra-LD series amplifiers and pair it with our CLASSiC DAC and/or a good quality CD/DVD/Blu-ray player. That will beat the pants off even the best record player/valve amplifier combination in terms of pure sound quality.

You shouldn't have to periodically reboot routers

Regarding the automatic NBN modem rebooter published in Circuit Notebook, September 2017 (www.siliconchip.com.au/Article/10786); I commend Les for an excellent solution to his problem. He obviously put a lot of thought into his design.

But I find it very sad that we as a country are spending over forty billion dollars to have the latest FTTP technology, which has in many parts of Australia been downgraded to FTTN and he has to design a homemade circuit to be able to use it to its full potential.

Geoff Hansen,
Littlehampton, SA.

Comment: the NBN roll-out has had many serious problems but we don't really think it's fair for it to cop the blame this time. Broadband modems have always been lousy and the fault lies with the manufacturers.

Remember the horrible days of slow dial-up internet? At least the good modems were programmed to "re-train" periodically in order to adapt to changing line conditions.

These days, DSL/cable/NBN modems only seem to adapt in one direction. When they detect interference on a given frequency, they stop using it and as a result, over time they get slower and slower until eventually you get frustrated and reboot it.

Then it is OK for a while until more random interference comes along and it slows down again.

Worse, many of them have dodgy firmware with memory leaks and other problems which causes them to either randomly reset or freeze up and require rebooting. So it really comes down to the cheapness of the modems and their poor programming, not the network itself.

Note that there is a mistake in the relay wiring of the circuit. See Notes & Errata on page 104.

Observations on Power Supply for Battery Radios

Having just read your article on the above excellent project in the August 2017 issue (www.siliconchip.com.au/Article/10751), I have made some observations.

It is commendable that we do everything we can to discourage the wrecking of battery radios and that includes the widely-held misconception that they can only be converted to mains sets.

That might have been the only practical approach in the 1950s and 60s but these days, we have ready access to simple components that make power supplies easy and logical.

The circuit does not have the resistors and capacitors numbered, to complement the text and overlays. This makes it difficult (especially for the less experienced enthusiasts) to follow.

As printed, D3 & D4 in the text refer to D3 & D13 in the circuit! In hindsight, they probably should have been labelled D3 & D4 in the circuit.

A good numbering practice is as follows. Where there are two or more distinct sections to a design, one section should be numbered C1, C2...R1, R2...D1, D2... etc. The next section is numbered C11, C12...R11, R12...D11, D12... etc or C101, C102...R101, R102... D101, D102... etc.

In the text, where it says "...and so the voltage doubler output will be about 85V, neglecting the voltage drop across diodes D1 & D2.", I think you intended this to read: "about 45V, neglecting...".

One other point, not mentioned, is that when using the "battery" sockets on the front panel, care must be taken

Want to work for Australia's Electronics Magazine

SILICON CHIP

If you live, breathe and sleep electronics you could be just the person we're looking for. While formal qualifications are well regarded, don't let a lack of letters after your name put you off, if you have the experience we're looking for.

The right person will certainly have skills in the following areas:

- ☑ **Analog and digital circuit design from concept to completion**
- ☑ **Circuit analysis and debugging**
- ☑ **PCB layout (we use Altium Designer)**
- ☑ **PC software development and embedded programming**
- ☑ **Operating electronic test equipment**
- ☑ **Mechanical design**

But most of all, you'll have the ability to write interesting articles (in English) describing what you've built and how SILICON CHIP readers can reproduce what you've done. You will have seen the style of SILICON CHIP articles – you're almost certainly an existing SILICON CHIP reader.

If you have skills in other areas which would help SILICON CHIP appear each month, tell us about them too: skills such as sub-editing, desktop publishing/layout, circuit drawing, photography, image processing, technical support/customer service (via telephone), project management, parts ordering and management, database administration, website design/programming and operating CNC equipment.

We don't expect you to have all these skills – but we'll help you to develop them as required.

You'll need to be highly self-motivated and able to work well by yourself as well as in a small team. Being able to work to the rigorous deadlines of a monthly magazine is vital.

Candidates will be given a six-month trial with a permanent position at the successful conclusion.

If you think you have what it takes, email your resume/CV (along with contact details!) to silicon@siliconchip.com.au

to ensure that the plugs carrying the +90V and B(-) wires are connected to the correct sockets.

Careless plugging can result in the joining link between the plugs actually shorting out the supply with less-than-desirable results.

Plug-in batteries came into being in approximately 1940-46; 1939 designs had pin tips and errors could be easily made. Power adaptors were offered by set manufacturers from the late 1940s and 50s, using sockets as you have done. But the accepted way of setting up these sockets was always to feed the 90V to one socket and provide the other with a shorting link to complete the circuit, thus it mattered not which plug went to which socket.

Geoff Trengove,
Maryborough, Vic.

Comment: you are right that the text incorrectly referred to D13 as D4. We're guessing that D13 was added to the design later, at which point D4 already referred to another component.

When we design a circuit, we sometimes renumber components after the final revision to avoid this sort of confusion but renumbering can also lead to errors.

Your point with the socket is a good one and the solution you have given is ingenious. If we revisit this design, we will wire the sockets up this way (it could possibly be done as a running change if we sell our existing stock of PCBs).

Finally, we think the reference to 85V regarding the output of the voltage doubler is correct. The input is 30VAC, which is around 42.5V peak, hence doubling this (via D1 and D2) should give around 85V. Consider that D1 and D2 are effectively connected across the B- and B+ 90V outputs.

Positive feedback from a happy reader

I want to say thanks to Leo Simpson as I spoke to him a couple of weeks ago when I rang about a Micromite kit I had purchased that was not working. We worked out a series of substitutions and determined the LCD touchscreen was not working. I received a replacement promptly and all is well now, thanks Leo.

Also, the article you published about Incat in the July 2017 issue was great. We were hiking in Tasmania in early April this year and I was wondering if Incat still existed. They seemed to not be all that well-known, even by the Spirit of Tasmania crew (some of them, at least).

It's great to see and hear stories that Australian companies can and do compete on the world market; even better when they are market leaders! We're not that backward after all!

Whilst on the subject of the magazine, I would like to say that I look forward to receiving my copy of SILICON CHIP each month.

The only complaint I have is that I read through it soon as I get it then I have to wait patiently another 4-5 weeks to get the next one. Perhaps I should not be wishing away the time waiting, maybe I need to learn some more patience! I'll try.

Another thank you is due here also. A long time ago, I emailed Leo Simpson about the Micromite and how it would be useful if some sort of tutorial could be published as well as the projects so people like me (microprocessor illiterate) could learn and get to understand the BASIC code used to program the devices. You and Geoff Graham have answered my prayers!

Geoff Graham deserves a medal for the massive amount of work he has put into the Micromite projects. He is absolutely brilliant and it is fantastic to see him so willing to pass on his knowledge to us not so brilliant.

Just one other point about the projects you publish. I love the Micromite projects you have published and have built several of them. This month you published an Arduino audio playback/recording shield, that's good.

It shows that your magazine is not biased, but as I am addicted to the Micromite I would love to see a similar project for the Micromite, I'm sure I am not alone here.

Keep up the good work!

George Wundele,
Belgrave, Vic.

Privatisation partly to blame for SA's electricity supply woes

I agree with your Publisher's Letter in the August 2017 issue, except for the part about the effect of CO_2 on climate which I am not competent to comment on.

The energy problems we have began years ago when energy production was privatised. State governments got an injection of money but lost the ongoing return from the production of energy and also lost any control over it.

I don't believe that our SECV would have shut down Hazelwood without arranging for replacement generation. Can you really envisage any private company building a power station where there is a lead time of five years or so and billions of dollars involved?

And then there is the stupid way that the government manages generation where various generators bid their prices and the generation on line is determined from these prices. It's no way to run a power supply system, in my opinion.

Then there is the 100MW Tesla battery being built in SA. This is half the size of one of the 200MW Hazelwood generator units and would last for a bit over an hour before it goes flat!

Batteries are worthwhile in domestic situations in order to get better value out of the PV system after the Sun goes down but not appropriate for the state-wide high voltage power supply system.

I don't know what the answer is to our energy problems but I don't have much faith in the current lot of our politicians to sort anything out.

Alex Brown,
Ashburton, Vic.

Editor's comment: companies regularly invest billions of dollars in projects which will not have an immediate pay-off but only if they expect to make their money back with a profit. We're not sure it's fair to blame privatisation.

If you ran a power company, given the present regulatory environment, would you make the decision to invest in a new base-load power station?

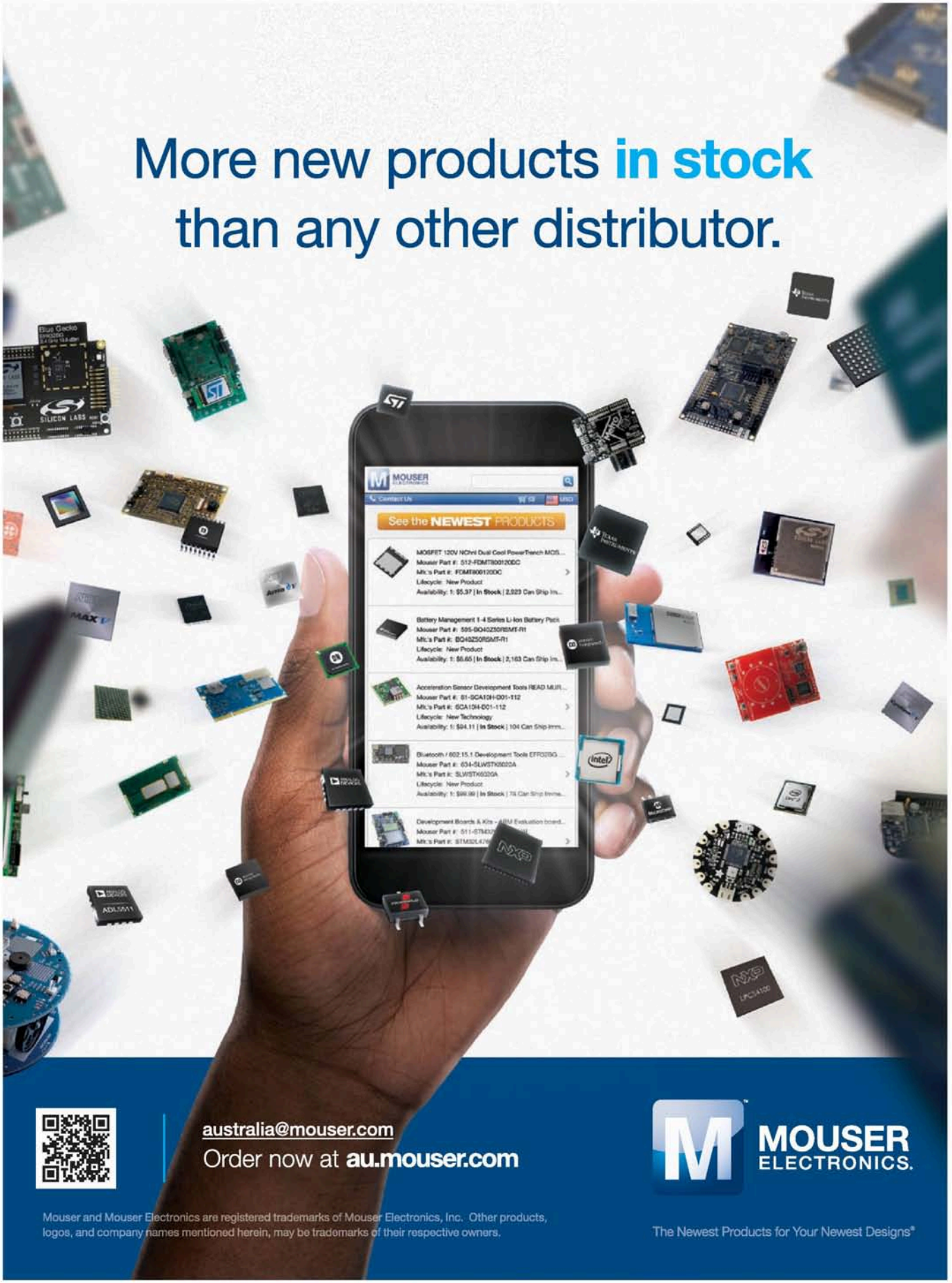
Micromite serial problem resolved

I wrote to you quite a while ago because I was having some trouble communicating with a 44-pin Micromite that I built from short-form kits that you supplied (see the August 2014 issue; **www.siliconchip.com.au/Article/7960**).

I purchased and built three; two worked fine but with the third, I had to set the FTDI chip to use a baud rate of 32,500 (rather than the correct value of 38,400) to establish communications.

At the time, you gave me some suggestions but I was unable to resolve this. I have since gotten to the bottom of this problem. I have determined that the FTDI chips are fine and other USB/serial adaptors gave me the same problem in communicating with that chip.

More new products **in stock** than any other distributor.



australia@mouser.com
Order now at **au.mouser.com**

MOUSER ELECTRONICS.

Mouser and Mouser Electronics are registered trademarks of Mouser Electronics, Inc. Other products, logos, and company names mentioned herein, may be trademarks of their respective owners.

The Newest Products for Your Newest Designs®

Given the fact that I had to set the USB/serial baud rate 18% low, I tried instead setting the Micromite's baud rate 18% high, to 45,288. This resulted in correct communications at 38,400 through the FTDI chip!

I then used the Microbridge (May 2017; www.siliconchip.com.au/Article/10648) to see if that would program this particular Micromite differently to the PICkit 3. It reported that the CPU ID was wrong and refused to program the Micromite at all.

The PICkit 3 reported "Valid but unexpected CPU ID, do you want to proceed anyway?" Answering yes allowed me to program the chip and it verified OK.

I therefore decided that the problem must be in the PIC32MX150 chip. Everything else seemed to work OK but the internal oscillator frequency seems to be 18% below what it should be, causing the serial communication problem.

I subsequently replaced this PIC32MX150 with the enhanced PIC32MX170, programmed it without a hitch using the Microbridge and tested at 38,400 baud. It now works fine.

Ingo Evers,
Higgins, ACT.

Getting on-soapbox about going off-grid

I felt compelled to write after the May 2017 Publisher's Letter about going off-grid maybe being a bad idea.

First, there's the scam of grid-connected solar. You (and the taxpayers) pay thousands of dollars for the small scale (expensive) infrastructure, yet you are rewarded with only 6c/kWh (in Victoria) for renewable energy.

They get a 25% cost reduction compared to what they pay for coal generation, plus they eliminate millions in infrastructure costs due to much of the peak load being supplied by solar.

How much did they contribute? Almost nothing. OK, they pay you a few cents for it and they let you use it all yourself if you want. Nice. Who got the better deal here, really?

The entire scheme was designed primarily to benefit them while throwing you a few crumbs. This is yet another reason to go off-grid. If you're going to spend thousands on solar make sure you get 100% of the benefit and they get a fat zero.

I do agree with using all your generated energy instead of giving it to them dirt cheap. But then let's stop and think what we are doing here. We are basically being forced to increase energy use just so that we don't give it to them! Is that the way we should be going?

We have been trained to consume far more than we really need. Yes, trained. We should be cutting back. Most of us are so addicted to energy consumption that our lives would be miserable without all our modern appliances we think we need but really don't.

If you are willing to cut back on the excesses of our modern living then going off-grid is not that hard to do, nor prohibitively expensive. For example, if you need a clothes dryer, disconnect the heating element.

So it takes three times as long to dry the washing – who cares? Now ask yourselves why the appliance manufacturers have not implemented such a huge energy saving initiative.

Answer: they don't want you to get anywhere close to detaching from your dependence and bondage to grid. Need more proof?

Look at modern washing machines: many have only a cold water inlet and the default programs all use 30, 40 degree and higher temperatures. That's an awful lot of energy unless you manually override and select cold each time.

How about a project which connects directly to solar panels and has variable output voltage to a heater element? (see www.easywarm.co.nz).

I'd say pool heating would be more of an energy issue to most pool owners than a couple of pumps running. For those that don't have heating, they could extend their season by installing one of these.

This kind of project could also be used as a direct connection to electric hot water heaters. Now that would be a real energy saving initiative by SILICON CHIP. The power companies would hate you for it though.

Robert Hatvani,
Noble Park, Vic.

Comment: All electric clothes dryers can be set to run at half power but the corresponding increase in drying time means that not much energy is likely to be saved. And trying to dry clothes without any heat input during wet cold weather simply won't work.

On the other hand, most people are aware that cold water washing works well and does save energy. There is no need to select cold water operation each time you turn on the machine; the setting will be remembered from the last time it was used.

Trying to heat a swimming pool with the average domestic solar installation is likely to be a futile exercise – far more power is needed and the pool would need to be covered every night to avoid heat loss. If you want to heat a swimming pool, dedicated roof collectors are the most effective solution.

Problems compiling Arduino sketches on a Mac

Just a note to advise on the use of a Mac running OS X and the Arduino IDE.

As suggested in your article, I installed the latest Arduino IDE software, version 1.0.8.3, running on Mac OS X 10.10. There appears to be a problem with the LiquidCrystal_I2C.h library with this version of the Arduino IDE; the lcd.print("string" or number) command will not print strings beyond the first (left-hand) character.

Repeated lcd.print(char) commands work OK, but of course this is not very useful. I checked the hardware, even substituting an older ATmega328 board I purchased some years ago. I also tried earlier versions of the IDE, V1.0.8 and V1.0.6.13, but to no avail.

The printing problem was resolved using the Arduino V1.0.6 IDE. Strings, numbers and assembled strings as you have used in the sketch print perfectly. Using this version of the IDE, however, raises another problem – the included EEPROM library does not support floating point numbers or the 4-byte EEPROM.put and EEPROM.get commands.

Since these occur in the NUDGE section of your sketch only, I am not too concerned, but I did rewrite the code there so that if nudging had been performed, there would appear a printout of the new value of CF (once the nudge switch was in the neutral position) while LK1 was in place. That new CF value would then have to be entered and saved in the global declarations part of the sketch, and the sketch recompiled. I can forward these changes to you, if you wish.

Since this situation is unlikely to occur too often, it's not really serious. But any of your readers using the latest version of the IDE on a Mac could be frustrated by the puzzling performance

of the I²C print library. Fortunately, the IDE V1.06 for Mac is still available. I am sending you my modified sketch code so that you can provide it to other readers who run into the same issue.

Anthony H. Goodman,
Worrigee, NSW.

Missing text in Radio Telescopes article

The article about Radio Telescopes in the August edition seems to be missing a section after the short paragraph in column 2 on page 16.

Would it be possible to publish this missing bit in the next edition? It was an interesting article. As an aside, on page 21 column 1 second paragraph, the past tense of "to lead" is spelled "led".

Alex Danilov,
Naremburn, NSW.

Publisher's response: Thanks for bringing this to our attention. The mistake happened because there was a slight change to the layout just before we went to press.

The missing lines are "... is set at a lower altitude. There is a talk about ALMA by Australian, Anthony ...".

Later HMV valve sets had 457.5kHz IF

I am currently burn testing a HMV E43F valve radio. While looking at the article on using a DDS module for IF alignment in the September issue (www.siliconchip.com.au/Article/10799), I noticed that the caption for Fig.4 may not be correct.

The HMV's peak response could well be correct if its IF is not resonant at 455kHz. Most HMV IFs in the latter years, including the one I just aligned, are designed for 457.5kHz.

Marc Chick,
Wangaratta, Vic.

Response: you're right that the HMV 64-52 was made with an IF of 457.5kHz. However, given that we're measuring a peak at 453.6kHz, that suggests it still needs tweaking for the optimum response.

Clarification on modifying Valve Radio Power Supply

I am very interested in the Mains Power Supply for Battery Valve Radio Sets published in the August 2017 issue (www.siliconchip.com.au/Article/10751). The project has some excellent features which I would recommend to anyone involved in this area of interest.

What I need to convey is that the overlay as produced in the magazine does not reflect some comments in the article about component numbers.

For example, my requirement is usually for 90/45V operation but the lack of component numbering on the circuit or published overlay has caused some difficulty in understanding how this was to be achieved.

It took a while but I can now see that the two lower 150kΩ resistors in the loading chain can produce the 45V if it is supplied through a 470Ω resistor from the anode of D3. I built a "mock up" of the 1.5V circuit and was pleasantly surprised to see a very low noise level, around 1mV peak-to-peak on this line.

Robert Forbes,
Forest Hill, Vic.

Response: the text on page 39 describing the modifications assumes you have the PCB in front of you, which has the resistors and capacitors labelled. We should have labelled the relevant components on the PCB overlay and circuit diagram to make it more clear.

As you surmised, the 470Ω resistor added is between the junction of the two 220µF capacitors at lower left in the circuit diagram and the junction of the two 220µF capacitors to their right. It essentially provides a low-pass filter for the existing 45V present at pin 8 of transformer T1.

For the modification to provide a 4V output for the A+ filament, R1 is the 100Ω resistor from the ADJ terminal of REG1 to the A- pin of CON1.

As you point out, this type of regulator is very good at rejecting 50/100Hz ripple when the ADJ pin is bypassed so the A battery output should have low noise.

BASIC as used in Micromite lacks error checking

P. C.'s problem with the Micromite code ("Quirks encountered with Micromite tutorial", July 2017 Ask SILICON CHIP) could well be due to a problem with the BASIC interpreter and language.

DO and FOR are both block open statements which need to be closed with a LOOP or NEXT statement respectively.

These can be nested (placed one inside the other) but once nested, the first LOOP statement closes the last opened DO block irrespective of what the code layout implies. Nice looking,

OCEAN CONTROLS

Helping to put you in Control

NFC Temperature Data Logger
sealed temperature logger for monitoring temperatures of products during transportation. NFC wireless interface and Windows software for configuration, download and charting.
SKU: NOD-052
Price: $59.00 ea + GST

Button Control Box
The green and yellow pushbuttons have 1 NO contact while the red emergency pushbutton has 1 NC contact.
SKU: HEE-025
Price: $27.50 ea + GST

IP watchdog monitoring module
TCW122B-WD is an IP watchdog monitoring module, specially designed for a failsafe monitor system. A relay is activated if there isn't an ICMP echo for a certain time.
SKU: TCC-004
Price: $114.50 ea + GST

Current Transducer
Split core hall effect current transducer presents a 4 to 20 mA DC signal representing the AC current flowing through a primary conductor. 0 to 30 A primary AC current range.
SKU: WES-0550
Price: $143.00 ea + GST

TECO Starter Kit
SG2-20HR-D Starter Kit. includes PLC, HMI and programming cable, with a 15% saving on the regular price.
SKU: TEC-081
Price: $393.00 ea + GST

Mean Well DC-DC Converter
100 W Isolated DC-DC converter module accepts 9.5-18Vdc input and gives 24 VDC out at up to 4.2 A.
SKU: PDC-010
Price: $83.60 ea + GST

LoopPowered Temperature Sensor
This is a simple 4 to 20 mA output loop powered temperature sensor with measurement range from -10°C to +125°C designed for monitoring RTU and PLC cabinet temperatures.
SKU: KTD-267
Price: $54.95 ea + GST

For Wholesale prices
Contact Ocean Controls
Ph: (03) 9782 5882
oceancontrols.com.au
Prices are subjected to change without notice.

correctly indented code will not save you from this error.

In some compilers/interpreters, there is no checking as to the correctness of the syntax of the block closing statement, which means a LOOP statement might close a FOR block and a NEXT statement might close a DO block. You won't necessarily find this error until you try to run the program and it actually reaches these lines (which may not happen very often).

The problem with IF is that, depending on the exact syntax used, IF can be a block open statement and END IF is (or should be) its matching block closing statement.

In the code as printed, with no syntax checking, LOOP (the last line) closes the IF block (second last line), leaving the DO block still open, hence the error message:

"DO WITHOUT LOOP"

The fix is to replace the last two lines of code with the following:

```
IF TOUCH(X) <> -1 THEN
  END
 END IF
LOOP
```

Chris Simpson,
Glenbrook, NSW.

Comment: it's true that IF can be a block open statement but it's also possible to have a single-line IF or IF/ELSE statement and in that case, you don't need the END IF.

The code as published (Fig.6 on page 28 of the February 2016 issue) is correct and will work if entered exactly as shown. But even slight changes or typos can mean that it won't work and may produce the "DO WITHOUT LOOP" message.

Comments on a range of topics

Reading Serviceman's Log reminded me of a recent repair I made. A few years ago, a product came out that was supposed to scare away snakes. I thought they were outrageously priced at the time, so I didn't buy one.

Instead, I thought about how they might work and made one from an old tape recorder motor with a small nut cable tied to the shaft, to unbalance it, and powered from a small solar panel from a junked solar light.

The whole lot was cable-tied to a star post and shook two or three posts either side of it when in operation. Two years later, it is still working. Anyway, a friend recently turned up with a set of solar-powered snake scarers and requested that I repair them, as they had cost $50 each a few years ago.

Upon disassembling one, I found it consisted of a single 300mA Nicad cell, a small PCB with an IC and some discrete components, plus a USB socket where the transducer plugged in.

Further testing revealed that the batteries were all dead and replacing these brought one to life, emitting a rather annoying chirp or three every few minutes or so.

Plugging and swapping around the working transducer revealed that the other units were also now operational but the transducers were faulty. Pressing apart the plastic spike revealed a small 1.5V DC vibration motor screwed to it.

What a let-down and a rip-off for $50 each! Anyway, I had a couple of old code practice buzzers in my junk box that were exactly the same as the dead ones. It only took a matter of minutes to replace them and then all three worked.

I estimate the cost of the components in these products to be less than $5. Do they work? I don't know but I haven't seen a snake in the area where I installed my homemade one.

In the Ask SILICON CHIP pages of the June 2017 issue, on page 108, P. W., asked about synthesising stereo from a mono recording. I re-record old recordings, some from the 1800s and have found that using the free audio program Audacity, a reasonable sense of presence can be created easily by doing the following.

After getting rid of the scratches, pops etc, select the entire recording and copy it to the clipboard, then make an empty second channel. Expand the time scale out so you can see a 50ms interval.

Select a point between 10 and 20ms from the start of the file and paste the copy of the original track into the second channel. This creates a stereo expansion effect with the second channel delayed from the first by about 20ms. It's simple and quite effective.

All you need to do then is rename the original channel to "left" and the new one "right" (or vica versa). Note though that with some music, you may find the resulting effect disorientating when listening with headphones.

Leo Simpson's comments regarding solar tariffs (Publisher's Letter, May 2017) stirred some memories of over 20 years ago when all this grid-feed stuff was being thrown around.

How binocular beam strain gauges really work

The Circuit Notebook item entitled "Measuring weight using Arduino" in SILICON CHIP, April 2017 (www.siliconchip.com.au/Article/10618) caught my eye because I have in mind a project involving a strain gauged pressure transducer.

With a little modification, the circuit and programming will provide a useful starting point.

However, incidentally, I noticed that there is somewhat of a misdirection in the brief explanation of how the strain gauges and the "binocular" beam function as a load cell. A side view diagram of the binocular beam was provided along with the circuit.

The accompanying text explained that: "When a load is placed on the free end of the beam, the beam flexes and the upper two strain gauges are in tension and the lower two are placed in compression." For a beam of the proportions shown that is not correct.

The given explanation would apply if it were a solid beam and if the strain gauges were connected so as to sense the overall bending moment in the beam.

However, in that case, the output signal would vary substantially depending on the load position.

That is because, the further the load is from the support, the larger the bending moment in the beam, the higher the bending stress and the higher the resulting signal from the strain gauges.

Such sensitivity to load position is undesirable in weighing applications such as platform scales. Rather than sense the overall bending moment, the binocular beam is actually configured to sense the overall shear force in the beam.

The advantage of that approach is that the shear force in the beam only depends on the magnitude of the load, not its distance from the support.

So how does the binocular beam sense the overall shear force? The key is to understand the function of the four thin sections of the member that remain above and below the two "binocular" holes.

These thinned-down sections effectively operate as flexural hinges,

albeit with a certain elastic stiffness that resists rotation of the "hinge".

Once they are recognised as hinges, it can then be appreciated that the binocular beam actually constitutes a parallelogram mechanism, with the four flexural hinges located at the corners of the parallelogram.

The notional parallelogram is illustrated by the green dashed line in Fig.1, which shows the binocular beam with exaggerated deflection under load.

The beam's mechanical resistance to being distorted in this way is mainly dependent on the elastic bending stiffness of the four flexural hinges.

When a load is applied, substantial bending stresses are induced in the thin sections that form the hinges and that causes change in the electrical resistance of the strain gauges that are bonded to the hinge sections.

(A strain gauge's electrical resistance varies according to the strain, that is the stress induced contraction or extension occurring along the surface to which it is bonded.)

The strain gauge on the top of the beam, nearest to the support, will indeed undergo tension strain, not so much from the overall bending moment in the beam but rather due to the local bending of the hinge.

However, in a beam of the proportions shown, and contrary to the explanation given in the text, the gauge on the top of the beam nearest to the loaded end will undergo compression strain due to the dominant effect of local bending of that hinge.

The opposite pattern applies to the gauges on the bottom of the beam. It is easier to understand that by reference to Fig.1, and remembering that when a part of a structure is deformed by bending.

In this case, the deformation is most pronounced at each of the flexural hinges; the bending causes tension stress and accompanying tension strain on the outside of the local bend and compression stress and strain on the inside of the bend.

A key feature of the parallelogram mechanism is that when the free end of the beam moves down under the effect of the load, it stays parallel to the fixed end of the beam, which in a weighing application, ideally should be horizontal.

Importantly, that also means that the bending moment and stress induced in the flexural hinges and hence the signal is not affected much by the where the load is placed on the load end of the beam.

That concept can be appreciated by thinking about the work done on the structure by the load. In an ideal device of this type, the gravitational potential energy lost by the load when it deflects the beam downward must equal the elastic energy stored in the distorted flexural hinges.

Thanks to the parallelogram mechanism, for a given degree of distortion of the hinges, the load moves downwards by the same amount irrespective of the load's exact position on the end of the beam.

The corollary of that is that a given load placed anywhere on the load end of the beam will produce the same amount of distortion of the hinges, irrespective of load position, and hence produce the same signal from the strain gauges.

That leaves the matter of the unwanted signal due to overall bending in the beam, which indeed will vary with load position.

Two factors help reduce this unwanted signal relative to that caused by the parallelogram action, which senses the overall shear force. The overall bending causes tension generally along the top of the beam and compression in the bottom.

However, one strain gauge on the top is connected into a tension leg of the Wheatstone bridge and one is connected into a compression leg, which means that the signal from overall bending is partially cancelled.

The cancellation is only partial because the overall bending moment varies along the beam, so the pair of gauges at the binocular hole near the load end generates a smaller signal from overall bending than does the other pair.

The closer the binocular holes are together, the better the cancellation but that reduces the parallelogram action so it is a design trade-off.

The other factor that helps reduce the unwanted signal from overall bending is that the bending of the hinges by the parallelogram action induces much greater stress than is induced by the direct forces in the hinges caused by overall bending of the beam.

Thus, the peculiar form of the beam, together with the electrical arrangement of the gauges, allows it to sensitively measure the overall shear force in the beam, and as far as possible, excludes and minimises the effects of the overall bending moment.

The parallelogram mechanism facilitates that by causing the overall shear force in the beam to manifest as localised high bending stresses and strains at the four flexural hinges.

A limitation of these devices is that they can be permanently deformed by overload.

This can be avoided by having a mechanical backstop located suitably close under the load end of the beam so as to limit excessive deflection.

Descriptions of other variants of this type of load cell, which have many diverse applications, can be found here: **www.sensorland.com/HowPage005.html**

Thanks for the great magazine. I have been reading it since its inception.

Nigel Beal,
BE FIEAust MIStructE RPEQ,
Chapel Hill, Qld.

Editor's response: thank you for a highly enlightening letter. The erroneous description of the operation of this type of load cell was introduced during editing; we can't lay the blame on the contributor for this one.

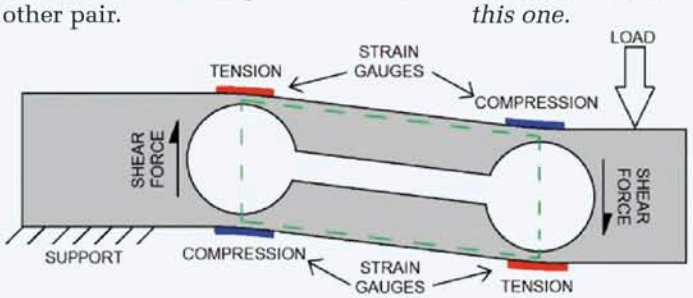


Fig.1: side view of binocular beam showing exaggerated deflection under load.

How common are rat attacks on cars?

I was completely immersed in reading the Serviceman story from B. Y., of MacKay, Queensland regarding the encounter with the dreaded scourge of the gnawing rat (August 2017).

It's almost a shame that it was in this section and perhaps, this letter may give that section more prominence. I have been a victim of this scourge not once but on several occasions with consequent huge repair costs and inconvenience.

Maybe no-one really wants to hear my hard-luck story and if it were only me and B. Y., then fair enough.

Except that when ever I bring this subject up in casual conversation, I never cease to be amazed at the sheer number of people who have similar tales of woe to tell. I suspect that this is just the tip of a very big iceberg.

Apart from being a curse to the vehicle owner, I believe that this is a hidden and serious public safety issue. This is especially the case with the pervasiveness of modern embedded electronic control systems – drive-by-wire (electro-servo throttle, all-electric steering, electronically controlled braking, etc).

With the increasing number of hybrid and all electric battery powered vehicles on the road, the risk of fire could be significant, which would be disastrous for those with internal garages!

I am sure the insurance industry is sitting on a bundle of statistics that would give the full breadth of scale to this issue but I am particularly incensed as to why, in the 21st century, car manufacturers seem completely incapable of designing and building vermin-proof vehicles without resorting to the application of chilli sauce! A few large public liability law-suits might get the ball rolling in the right direction!

In the meantime, I would be most interested to hear more tales from other readers on this subject but in particular, stories from automotive electricians who by far, would be most likely to encounter the worst of it.

You know, I've always believed that if you could put a rat in charge of the training of a US Navy Seal you would produce a truly unbeatable, "universal" soldier!

Andre Rousseau,
Auckland South, New Zealand.

We engineers argued for a net tariff, where the meter basically went fowards when you were using power, and backwards when you were exporting power.

At the end of the billing period, if the meter was positive, you paid up, if negative, the supply authority paid you, at the same rate.

This is called parity pricing and would have been a fair way of paying for your energy. This was rejected by the powers-that-be because they wanted to keep track of the energy being generated to raise the solar renewable energy certificates (RECs) and metering at that time didn't allow recording of input and output power independently. Also, the case for different tariffs for grid feed-in was raised.

This is of necessity a simple explanation of a very complicated system and now we have the situation where you may get paid say 6c/kWh for your power, whilst getting charged something like 50c/kWh to use energy from the grid in peak periods.

I have seen some systems that were not correctly wired where the customer was getting charged 50c/kWh for their own generated power, whilst getting only 6c/kWh for power fed into the grid. This could explain why some people find their electricity bills are still so high, even after the installation of a solar system.

I suspect that this has been done on purpose in some instances, to make more profit for the retailer. As to Leo Simpson's comments regarding battery systems and maintenance costs, yes, the initial purchase cost of batteries is high but maintenance costs are nearly zero with sealed deep-cycle batteries and correctly adjusted regulators etc.

Indeed, 20+ years' life from this type of battery is the norm, at 10% maximum discharge. I suppose it comes down to demand; if people want to have batteries for secure power (and load shedding at peak times to save money from the demand tariffs), then the market will respond appropriately.

Finally, I would like to point out that a diesel-electric submarine will always be quieter than a nuclear submarine, and that's because the nuclear submarine needs coolant pumps operating continuously to cool the reactor.

Nuclear subs are also detectable by other methods, such as looking for a place in the ocean where there is more hydrogen in the sea water than there should be (the process of making oxygen from sea water leaves hydrogen and a waste product which is dumped back into the sea).

Other methods for detecting subs are looking for a quiet spot in the ocean, as modern submarines are insulated to absorb noise, analysing the sea water to detect traces of shaft seal oil and looking for a large, moving magnetic anomaly in the sea.

Peter Laughton,
Tabulam, NSW.

Editor's comments: while you are right that a good quality battery bank could last 20 years or more, limiting depth of discharge to 10% means that if your maximum daily consumption was say 5kWh (including aircon, fridge, laundry, etc) you might need a bank of around 50kWh to keep the average depth of discharge at 10%. You may possibly need more to account for multiple days of poor weather, which would make for a huge and very costly battery bank.

Replacing this every 20 years (or so) would work out to a very large maintenance cost when amortised over that period.

You would also need to factor in the panel life-span (maybe similar to the batteries) and inverter(s), which can fail after just a few years' service. These all need to be factored into a proper cost/benefit analysis.

By the way, one reason lithium-based storage batteries like the Tesla Powerwall are so attractive is that they can handle a much greater depth of discharge without shortening their lifespan dramatically, so you don't need nearly as much capacity, making them more cost competitive; even occasionally flattening them should not harm them.

Regarding your comments on nuclear submarines, some modern submarine reactors can operate at low power levels without active coolant pumps so they aren't necessarily much noiser than a lurking diesel sub. SC

Launch of WRESAT, 29th of November 1967. Note the kangaroo logo on the side of the rocket. There is also a woomera (Aboriginal spear thrower). The rocket had been painted white (brushed, not sprayed, apparently!) to assist tracking but beneath that paintwork remained the greenish US Army colour scheme, some of which is visible on the recovered Stage 1 vehicle (see page 21).
Photo courtesy Defence Science and Technology Group, Department of Defence.

WRESAT: Australia joins the space race... fifty years ago!

Most people would not be aware that Australia was just the seventh country to put a satellite of its own design into orbit. Just ten years after the launch of Sputnik, Australia successfully launched "WRESAT" from the Woomera Rocket Range in South Australia. On the 50th Anniversary, Dr David Maddison takes a look at what, for the time, was a remarkable achievment.

After the Soviet Union launched "Sputnik" in 1957, the United States launched Explorer 1 in 1958, then the United Kingdom followed in 1962. Canada (also in 1962), Italy (1964) and France (1965) had also launched satellites.

Australia followed when it launched its first satellite, WRESAT, in 1967. Its name (pronounced "reesat") is a shortened form of the Australian Weapons Research Establishment (WRE) SATellite.

Incidentally, Australia was just the third country to launch a satellite from its own territory, after the USSR and USA. (France is often claimed to be the third country to launch from its own soil but their launch was from post-colonial Algeria).

This satellite gave Australia membership of the then-exclusive "space club" which at the time only had the six members mentioned above. It also gained wide publicity in Australia and worldwide.

The entire project was one of exploiting available opportunities such as the availability of a largely US-built rocket providing the launch vehicle, a "can do" attitude, government support with minimal interference and a rapid build of the satellite which took only 11 months and was done on a small budget.

The USA had been using rockets at the Woomera Rocket Range (as it was then known) in South Australia, in a collaborative research program with Australia and the UK called Project SPARTA (SPecial Antimissile Research Tests, Australia).

The purpose of the project was to test the various physical effects involved in high speed re-entry of nuclear warheads into the upper atmosphere.

Ten rockets had been shipped to Australia but only nine were used. The options were to return the tenth rocket to the USA at great expense or alternatively, according to an idea put forward by the Australians, the rocket could be used to launch a small satellite.

The Americans thought the idea was excellent and offered a team to prepare the rocket as well. The gift of the rocket was a reward for the great Australia-US friendship and long-term involvement in NASA tracking.

There was a challenge, however: the Americans and their team would be leaving Woomera in 12 months hence, which meant that a satellite had to be designed, built, tested and launched within that timeframe.

This wasn't the first offer the USA had made for Australia to use one of their rockets. According to a biographical article about University of Adelaide's Professor John H. Carver, there had been a previous offer

ALL SYSTEMS GO...

Wresat circles the earth

ADELAIDE, Wednesday. — Wresat 1 — Australia's first satellite — is now looping around earth every 100 minutes at five miles a second and returning scientific data to tracking stations around the globe.

By midnight the small 160-pound satellite, which is about as big as Russia's first Sputnik, had begun its sixth orbit around earth.

The Redstone Rocket was launched at 2.48pm (Canberra time) right on schedule.

The Redstone failed to ignite at the first attempt. But today ignition came as planned, 23 seconds after the countdown to zero.

The rocket rose slowly from its launch area with the black painted Wresat satellite clearly contrasted against the white body of the American rocket.

It took Australian scientists and engineers 12 month to design and build the five-foot conical satellite.

Copybook flight

Wresat was launched today after a trouble-free countdown which led to a copybook flight by the Redstone rocket which is similar to the one which launched America's first satellite in 1957 and its first astronaut in 1961.

On its first orbit, data from the satellite was picked up by Gove in the Northern Territory, Guam and Fairbanks in Alaska, St Johns in Newfoundland and San Diego in Chile.

The burnt-out first stage of the rocket fell to earth as planned in the Simpson Desert north of Woomera, and the second stage somewhere in the Gulf of Carpentaria.

Wresat is expected to be effective for between 7 and 10 days and to remain in orbit for about 40 days.

It will measure cosmic and solar radiation in the ultra-violet and X-ray regions and carry out various other measurements which will give a clearer picture of how these affect the upper atmosphere in relation to earth's climate.

The Redstone rocket with its satellite leaves the launching pad at Woomera yesterday. — Picturegram.

(Above): "*The Canberra Times*" of 30th November, 1967 – "All systems go!" (Below): Australia joins the "Exclusive Space Club", a cartoon of the time. Unfortunately, many have forgotten or don't know that Australia was ever a member. There is an error in the cartoon where it says we were the fourth nation to launch a satellite – we were seventh overall, although the third to launch a satellite from our own soil.

"I THEENK ZE NEW MEMBER SAID 'STEAK 'N EGGS 'N GROG!"

A photo from the Adelaide Advertiser, November 14, 1967, showing key WRESAT personnel: (L-R) Project Manager Des Barnsley (WRE), Professor John H. Carver (UA), Bryan Rofe (Scientific officer in charge, from WRE) and WRE Director Dr Don Woods. Note the antennas about one third of the way up the body.
Photo courtesy of Professor John A. Carver, son of Professor John H. Carver.

in 1960 but there was no interest in space research by the Australian Government at the time and so the offer was declined.

Prior to that, Australian scientists had tried to get access to rockets being launched at Woomera as part of the Australian contribution to the International Geophysical Year in 1957–58 but they could not; one of several very disappointing missed opportunities.

The proposal for an Australian satellite received high-level approval from the government at the end of 1966 and with a minimum of bureaucratic interference the project was initiated.

One of the reasons cited for approval was national prestige, others being the relatively low cost of the project and also giving staff at Woomera experience in satellite launches.

NASA agreed to provide tracking and data acquisition services for the project via their Satellite Tracking and Data Acquisition Network (STADAN) while Britain also offered support by the use of their facilities. NASA also donated the data tapes.

There were a lot of very smart and committed people involved in this project but in this article, we will focus on the science and technology rather than the people within the team and their specific involvement.

This has been documented elsewhere such as in the book "Fire across the Desert: Woomera and the Anglo-Australian Joint Project, 1946-1980" by Peter Morton.

Designing and building the satellite

The WRESAT satellite itself was designed and built as a joint project between the Weapons Research Establishment (WRE) of the Department of Supply and the Physics Department of the University of Adelaide.

They were already cooperating on a research program with the use of locally developed sounding rockets and payloads for upper atmosphere measurements for climate research.

Given the short time frame available, it was logical to build upon the existing work and expertise of these upper atmospheric measurements.

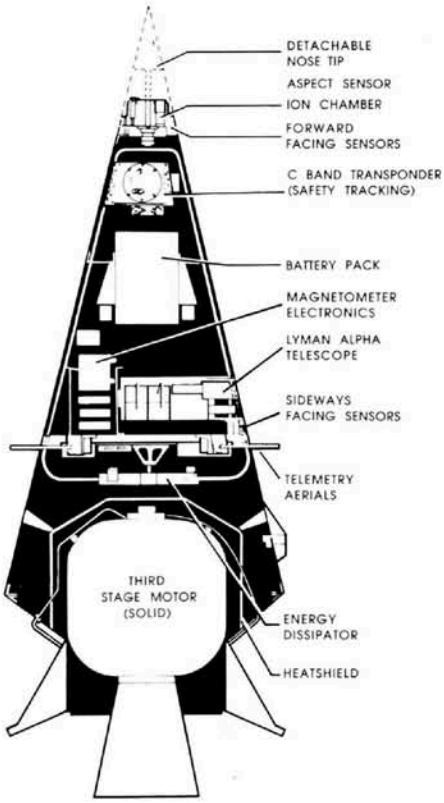
A satellite offered many advantages over sounding rockets (rockets carrying instruments to perform experiments during sub-orbital flights), such as measurements over a much larger time scale than the few minutes permitted by sounding rockets, plus the ability to make measurements at any point on the earth's surface.

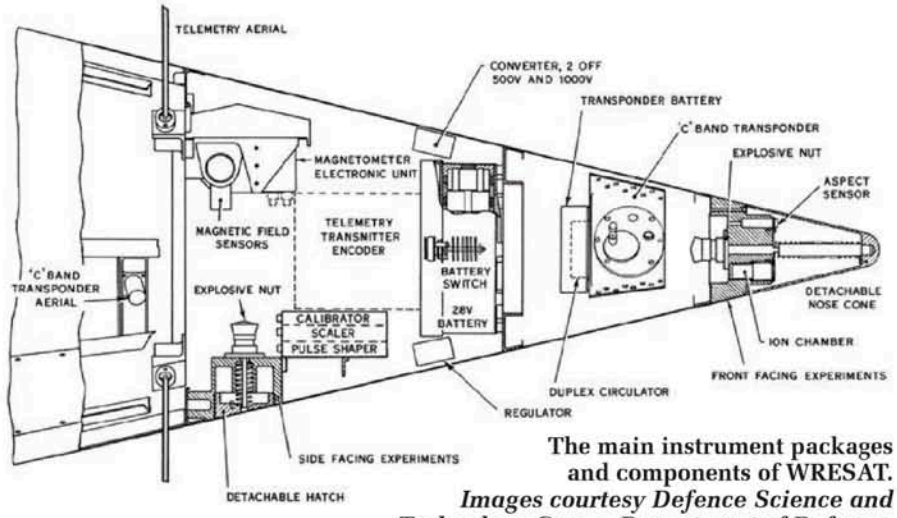
As mentioned above, the launch vehicle and vehicle preparation team were provided by the USA, specifically the Advanced Research Projects Agency of the Department of Defense (DARPA) through the US Army Missile Command.

This team included private contractors from Thompson Ramo Wooldridge Systems (most recently known as TRW, Inc. but defunct as of 2002, when it was acquired by Northrop Grumman).

WRESAT was built in the form of a cone which formed the top of the rocket, rather than the traditional design which was contained within a jettisonable fair-

Vacuum chamber at the University of Adelaide in which WRESAT was tested to ensure its systems would tolerate a vacuum.
Photo courtesy of Professor John A. Carver.





The main instrument packages and components of WRESAT.
Images courtesy Defence Science and Technology Group, Department of Defence.

ing. Presumably this was done for space efficiency and simplicity.

The mechanical construction was in the form of a ring and stringer design, meaning the round shape was established by a series of rings connected by a series of long strips or "stringers", a typical aerospace type of construction.This was covered by an aluminium skin 1.2mm thick. This is about two to three times the thickness of the skin of a light aircraft.

Three satellite cones were built. The first was used as a model for the structural design, the second was used for checking the internal arrangement and accessibility of components and the third was the actual working one launched into space.

The exterior of the satellite was painted mostly black and the interior was white, both colours chosen to aid in thermal management. On the exterior, there was also some silver striping to give a balance between heat absorbed on the sunlit side and radiated on the shadow side.

An interesting anecdote is that what was thought to be a special aerospace grade white paint was imported at great expense from the USA and 15 coats had to be applied in a marathon 48 hour painting session. But it turned out that the wrong paint was sent and it was the equivalent of house paint. Despite this, it worked fine.

WRESAT itself was 159cm long with a base diameter of 76cm and a weight of 45kg without the stage three motor. Including the third stage, it weighed 72.5kg and had an overall length of 217cm. After burn out, stage three (including its motor) remained attached to the satellite by design.

In comparison, the Soviet Sputnik 1 weighed 83.6kg and had a diameter of 58cm and the US Explorer 1 weighed 13.97kg and was 205.1cm long and 15.2cm diameter. Those satellites were the first for both countries.

Part of the satellite testing included placing it in a vacuum chamber at the University of Adelaide, to ensure its systems would tolerate the vacuum of space.

Static, vibration and shock testing was also done to ensure the satellite would tolerate the shock of launch and high acceleration forces. Shock testing was done to 40g.

As the satellite was to spin, it also needed to be properly balanced and this was done on commercial Repco equipment used for engine balancing. Radio testing was also done to determine that the antennas and telemetry worked correctly along with the tracking transponder. Temperature cycling was done between -15°C and +50°C.

WRESAT structural model undergoing vibrational testing.
Photo courtesy Defence Science and Technology Group, Department of Defence.

WRESAT was powered by batteries (one mission battery and one for the tracking transponder) rather than solar panels, as back then they were not off-the-shelf items and an array would have to have been designed and built which would also have also complicated the design. There was not enough time to do this.

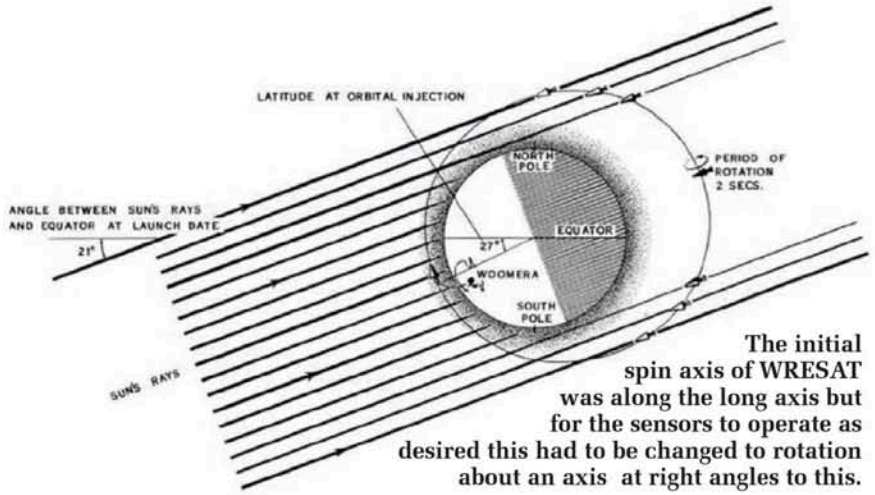
The battery type is not disclosed in the available literature but looking at spacecraft battery technology of the period, we speculate that they may have been silver-zinc batteries with a potassium hydroxide electrolyte, such as were used on the Apollo Lunar Module which had a battery voltage of 28V, the same as the battery on WRESAT. The batteries were intended to last about 10 days and the orbital life was expected to be 40 days.

The satellite had two sensor ports, one at the apex of the satellite and one at the side. These were protected by covers during ascent and were later released by explosive nuts. There were also telemetry antennas external to the body of the craft.

Instruments and sensors

The measurement sensors in the forward port were three ion chambers, an ozone sensor and an aspect sensor. The side port had three ion chambers, a Lyman α (alpha particle) telescope and an aspect sensor. Other equipment on board included an X-ray counter, telemetry transmitter, a magnetometer, a transponder for tracking, a power supply and the batteries.

Preparing WRESAT, showing some detail of the electronics packages. Note part of the third stage rocket motor visible in the lower portion of the vehicle. *Image courtesy of Professor John A. Carver.*



The initial spin axis of WRESAT was along the long axis but for the sensors to operate as desired this had to be changed to rotation about an axis at right angles to this.

The ion chambers measured UV light at three wavelengths which strongly affect the atmosphere; one of the wavelengths had never been measured from a satellite before. The same sensors could also be used to measure the temperature of the Sun's atmosphere and the density of molecular oxygen in the atmosphere.

There was also a photodiode sensor to measure ozone in the atmosphere and an X-ray counter. The Lyman α telescope measured UV radiation from hydrogen atoms around the earth.

WRESAT telemetry

WRESAT transmitted telemetry data at 136.350MHz with a power of 0.1W. There were 29 channels of data, 15 for the scientific instruments plus 14 for housekeeping functions such as battery voltage and internal temperature. Apart from their data content, the signals were also used by NASA's STADAN network to track WRESAT.

Ground stations recorded telemetry signals on tape but were not able to decode the data so the tapes had to be sent back to Australia for analysis. It is not clear how tracking continued after the main battery weakened but we speculate that this was done via the C-band transponder.

Science program

WRESAT was primarily designed to conduct atmospheric research, with a particular emphasis on how atmospheric properties affect weather in Australia, the ability to conduct weather forecasts and even "controlling the weather". This was a topic of significant interest, especially cloud seeding research, as was being done in Australia at the time.

It was a natural extension to the collaborative work already being conducted between the University of Adelaide and WRE using sounding rockets to measure parameters of the upper atmosphere and for which expertise had already been developed.

Other objectives of the WRESAT program included the development of Australian scientific and technological expertise related to satellite development and management of complex projects of this kind and also assistance to the USA with its research programs.

There were four experiments on WRESAT. These were based upon or derived from earlier work that was done with sounding rockets. Two experiments were designed to measure ultraviolet radiation from the sun, one was to measure faint ultraviolet halo from the earth at night and another experiment was to measure X-rays from the sun.

Satellite spin and energy dissipation mechanism

In order for the satellite to be effective, it had to achieve a certain orientation and rotation. After the burn-out and separation of the first stage, the satellite (with stages two and three still attached) coasted to an altitude of about 185km, the inertial guidance system having placed the spacecraft into a horizontal position with respect to earth.

Spin rockets were then ignited to cause the spacecraft to rotate about its long axis like a rifle bullet, with a roll rate of around 2.5 RPM. Stage two was then ignited and was discarded

Woomera Launch Area 6 (LA-6), one of a number of launch facilities that once existed at Woomera. This pad was last used in 1970, most recently by the European Launcher Development Organisation to develop a European rocket although no satellites were ever successfully launched. European satellite launches are now mostly conducted from French Guiana. This pad was not used by WRESAT but is shown to indicate the extensive nature of the launch facilities that were available. Sadly, the historic significance of this pad was not recognised and only the concrete remains today.

after burn-out. Stage three was then ignited to insert the satellite into its final orbit, at an initial speed of around 28,500km/h and an altitude of 185km.

With ideal balance and no friction, the satellite would continue to spin on its long axis indefinitely (like a rifle bullet) but just as a (non-ideal) spinning top eventually starts to move off axis or "nutate" as it loses energy, so did the satellite. This is because no system is perfectly balanced or rigid and spin energy is lost, causing the axis of rotation to change to the one with the greatest moment of inertia (which in this case was not the long axis). In fact, this behaviour was both expected and desired.

The desired spin axis was not the long axis but one at right angles to the long axis, with the head spinning front over end and the axis being parallel to the original spin axis of the satellite at its start of orbit. The new spin rate was 0.5 RPM, as determined by the ratio of the axial mode to tumble mode inertia.

The change in spin axes was facilitated by an energy dissipation device in the form of a metal tube containing silicone oil which acted to slow the rotation, removing some spin energy (as with a spinning top that moves off axis), due to the movement of the oil in the tube dissipating energy in the form of heat.

The transition would have happened anyway but purposefully dissipating some of the energy sped up the process which was achieved within one or two orbits, compared with the much longer time that would have been taken if relying on the natural energy dissipation processes on the satellite, such as flexing of the body.

The phenomenon of certain rotating objects changing their spin axis in space is shown in the video "Rotating Solid Bodies in Microgravity" at siliconchip.com.au/link/aafz

The front-over-end rotation was needed so that the satellite sensors, which had a field of view of 80°, could scan the Earth and Sun.

The launch

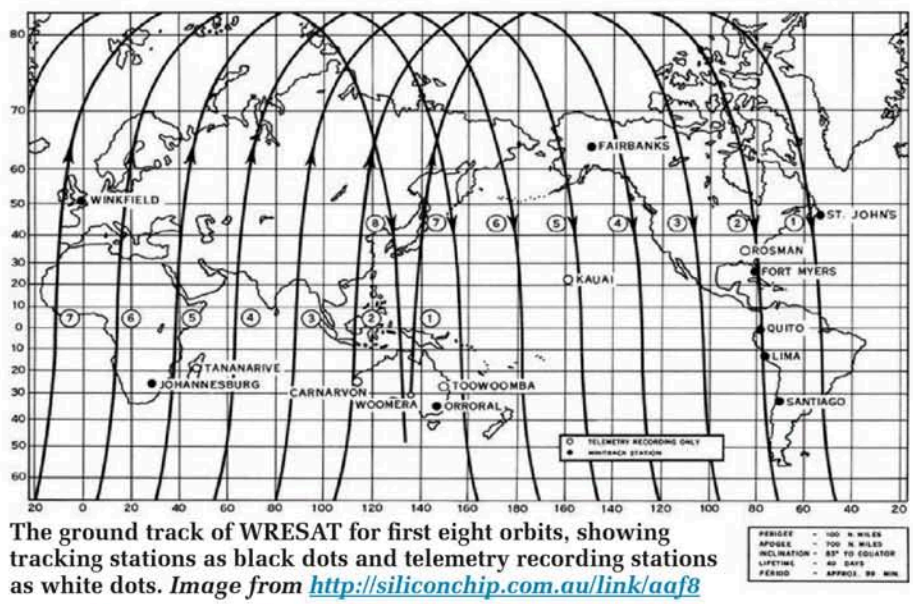
Due to a fault in an umbilical connection to the rocket, WRESAT did not launch on November 28th as planned, causing great disappointment to many dignitaries who had attended. However, the next day, WRESAT was launched at 2:19pm local time. The launch went flawlessly.

Two minutes after the launch, stage one burned out and separated. Stages two and three continued and then the spin motors fired, to cause the satellite to spin on its long axis. Stage two was fired and burned out at 30 seconds, separated and fell toward the Gulf of Carpentaria. Stage three fired for nine seconds, finally propelling WRESAT to its orbital velocity.

The first incoming telemetry from the rangehead was good and it was confirmed that the instrument port covers were ejected but it was not yet confirmed that WRESAT was in orbit. The next telemetry came in from Gove which was also good. Guam was the first NASA STADAN tracking station to receive telemetry followed by Fairbanks, Alaska. Things were looking good!

At Fairbanks, it was noted that the spin rate had decreased from two to 0.7 revolutions per minute, on its way to 0.5, and the change in spin axes was happening faster than expected.

The next STADAN stations to receive telemetry were St Johns, New-



The ground track of WRESAT for first eight orbits, showing tracking stations as black dots and telemetry recording stations as white dots. ***Image from*** ***http://siliconchip.com.au/link/aaf8***

foundland; Rosman, North Carolina; Quito, Ecuador; Lima, Peru and Santiago, Chile. Twenty-five minutes after the Santiago contact, telemetry was received at Carnavon, WA.

This proved that WRESAT had completed an entire orbit and the mission was a success.

WRESAT transmitted useful data for 73 orbits each of 98.974 minutes' duration over five days, until the main battery was too weak.

The satellite eventually completed 642 orbits over 42 days, re-entering the earth's atmosphere on January 10th, 1968 just before 12 noon GMT, between Ireland and Iceland. Note that the number of orbits corresponds to 44 days, not 42; it is not clear why there is a discrepancy.

Launch location and trajectory

WRESAT was launched over what was arguably one of the finest rocket ranges in the world, which was then known as the Woomera Rocket Range and is now known as the RAAF Woomera Test Range.

One of Woomera's great advantages was the largest overland downrange distance in the Western world of 2250km, from Woomera to the north coast of WA, making parts recovery relatively easy for post flight analysis.

Having been established as a joint venture between Australia and the UK, in the 1950s and 1960s it was the second-busiest rocket range in the world next to Cape Canaveral. WRESAT was launched into a polar orbit so the trajectory was to the north, rather than toward the north coast of Western Australia.

There is some variation in the reported orbital parameters of WRESAT but according to Fire Across the Desert, the perigee of the orbit was 169km and the apogee was 1245km.

On the other hand, according to the 1968 annual report of the Department of Supply, it was 177km x 1287km. Another figure cited is 198km x 1252km.

The most correct figures likely come from NASA's computed orbital elements for this flight, designated 1967-118A and issued on 29th November, which are 170km x 1249km.

According to those orbital elements, the orbit was nearly polar with an inclination from the equator of 83.3°. The velocity at apogee was 25,016km/h and at perigee, 29,137km/h.

Range safety and satellite tracking

Safety over the rocket range was always a top priority at Woomera and while no one would want to do it, if the rocket veered out of control, it would have been necessary to press the self-destruct button. The rocket self-destruct mechanism was called WREBUS.

Because of its northerly track, it was not clear whether the self-destruct radio signal could reach the rocket or whether it would be attenuated by the second stage rocket flame. A decision was made to install a WREBUS transmitting station at the Oodnadatta Airfield to ensure a signal could get through.

One of the two FPS-16 radars used to track WRESAT at launch. *Image source:* siliconchip.com.au/link/aaf8

To ensure that the rocket remained on track or to detect any deviation from the planned track, its progress was monitored by observers using optical trackers plus a pair of FPS-16 radars which were part of the range facilities.

One of the radars was located 40km from the beginning of the range and the other 115km south of Coober Pedy.

The radars could track a target out to at least 971km and a ranging error of as little as five metres was possible. These radars operated around 5.5GHz, with up to 1MW of output power.

There was also a Digital Impact Predictor which had been developed for the Blue Streak and Europa programs, to predict impact points of the rocket stages or debris.

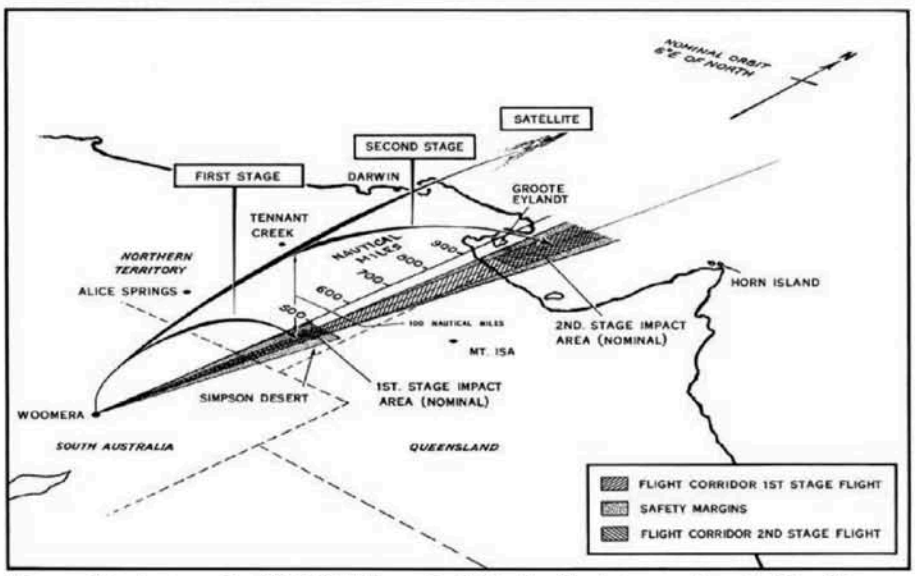
The radars could operate in either the conventional mode, whereby they detected a reflected signal from a target, or in "beacon" mode whereby a coded signal was transmitted from the radar which triggered a C-band (4-8GHz) transponder on the spacecraft. This then replied with an appropriate signal.

The transponder was a special unit, model SST-135C, designed to work with this radar equipment.

This allowed a much greater range and the spacecraft could be tracked up to the point of orbital insertion and beyond.

In the diagrams of WRESAT, the C-band transponder is visible and it can be seen to have its own battery pack.

While not stated anywhere in the literature surveyed for this article, it is assumed that the C-band transponder remained active for the life of the mission, even after the main satellite battery had become weak.



Planned trajectory for WRESAT launch. Note the first stage estimated landing area in the Simpson Desert. Dick Smith found the stage in 1989. There is speculation that the second stage did not land but burned up on re-entry. The northerly launch corridor was one of two that were possible from Woomera, the other being the launch corridor to the north west. *Image courtesy of Defence Science and Technology Group, Department of Defence.*

This would have been how the satellite was tracked throughout its orbit (via other radar stations around the world) and its re-entry point determined. That is speculation by the Author, however.

The radar system and its various modifications were considered cutting-edge technology for the time. The radar system was also used by NASA to track Mercury and later spacecraft.

The launch vehicle

While the satellite was of Australian design, as stated earlier, the SPARTA launch vehicle was donated by the United States. It was a three-stage rocket that used a Redstone missile (SRBM) with 416kN thrust as its first stage. This was fuelled with liquid oxygen and Hydyne, a mixture of 60% unsymmetrical dimethylhydrazine (UDMH; similar to hydrazine) and 40% diethylenetriamine (DETA)

This is somewhat more powerful but also more toxic than the alcohol/water fuel used in earlier Redstone rockets.

The Redstone was America's first large short-range ballistic missile and was capable of carrying a 3100kg nuclear warhead 280km. In other applications, it had a range of up to 323km. It was a direct descendant of the German V-2 rocket of World War 2 and was mainly designed by German engineers who had been bought to the USA after the war.

The rocket was produced from 1952 to 1961 and retired from use by the US Army in 1964 after which many surplus rockets were put to alternative uses such as tests and satellite launches, including WRESAT.

The Redstone missile was also modified and used to put America's first astronaut into space (John Glenn).

SPARTA's second stage was a 93kN Antares 2 (designed by Thiokol, also known as X-259). This was originally the third stage of the USA's Scout four-stage solid fuel rocket, also designed for launching satellites.

The third stage was an Australian-designed BE-3, by WRE (Weapons Research Establishment), with 34kN thrust. This also used solid fuel.

In order to conduct firings of the SPARTA rockets, including the one that launched WRESAT, some equipment that had previously been donated to the Smithsonian Institution for museum display had to be borrowed back. WRESAT was the last launch that utilised a Redstone missile and was considered a great end to the career of this excellent and successful rocket.

At launch, the SPARTA rocket with the WRESAT payload weighed around 25.8 tonnes and the Redstone motor developed 34.0 tonnes of thrust for 122 seconds.

These figures come from the booklet describing WRESAT from WRE, however, Wikipedia quotes 30.0 tonnes as the mass of a SPARTA launch vehicle with 42.4 tonnes of first stage thrust and a burn time of 155 seconds.

It is therefore conceivable that the launch used a lesser fuel load than normal for the WRESAT mission.

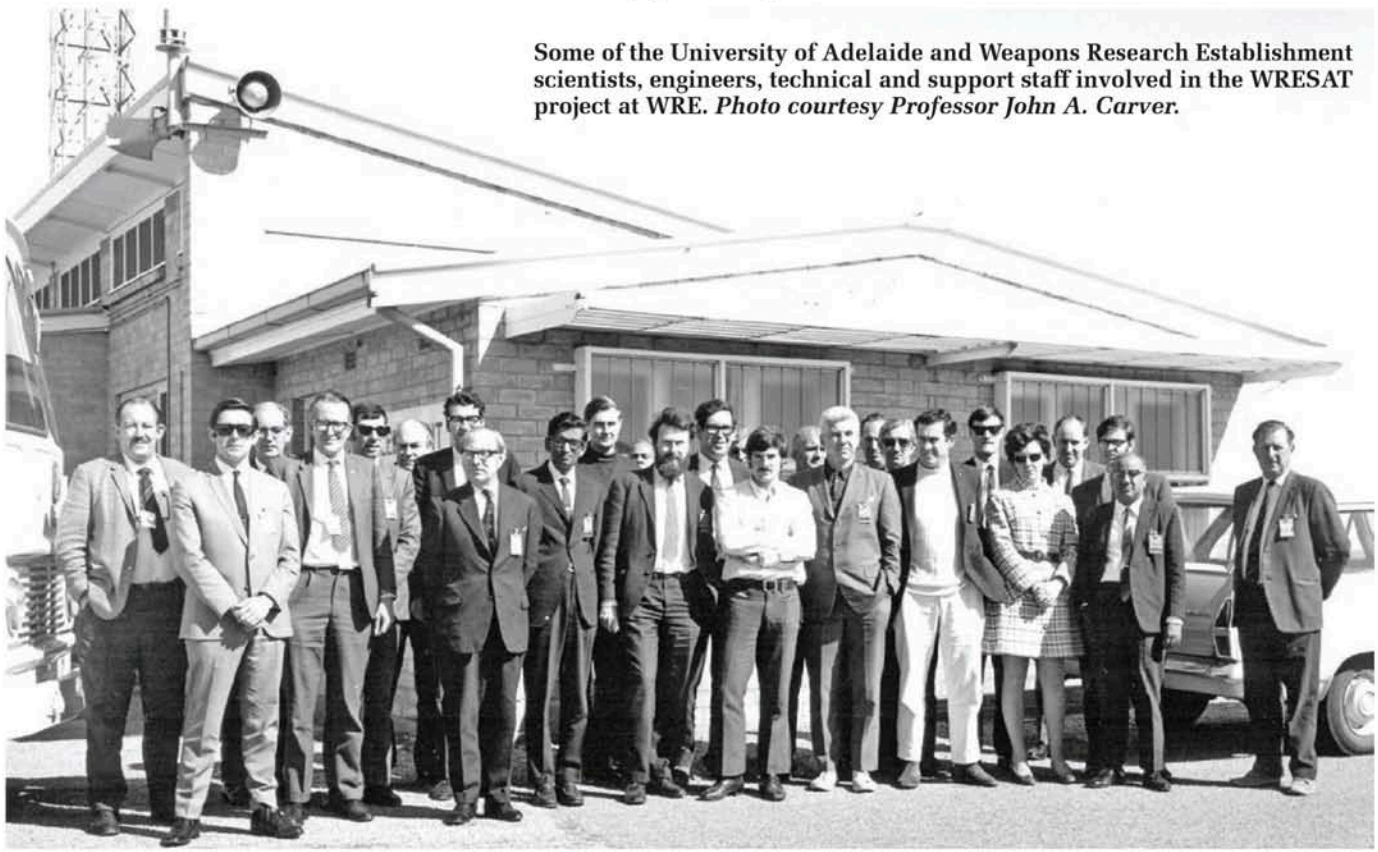
Dick Smith undertook an expedition in 1989 to find the first stage of the rocket vehicle in the Simpson Desert (see box). The second stage was designed to land in the Gulf of Carpentaria and has not been found (it's unlikely that it ever will be).

The re-entry of the second stage was not observed and it is speculated it may have burned up as it fell back to earth.

The third stage remained attached to the satellite. This was intended to eliminate the added complexity of a separation mechanism.

Congratulations

After the successful launch, congratulations were received from numerous places, including a radio broadcast from Prime Minister Harold Holt, who said it was "a notable sci-



Some of the University of Adelaide and Weapons Research Establishment scientists, engineers, technical and support staff involved in the WRESAT project at WRE. *Photo courtesy Professor John A. Carver.*

Event Cover for WRESAT launch with 5c stamp issued by the Postmaster-General's Department. *Acknowledgement Dr Ross J Smith:* siliconchip.com.au/link/aaf9

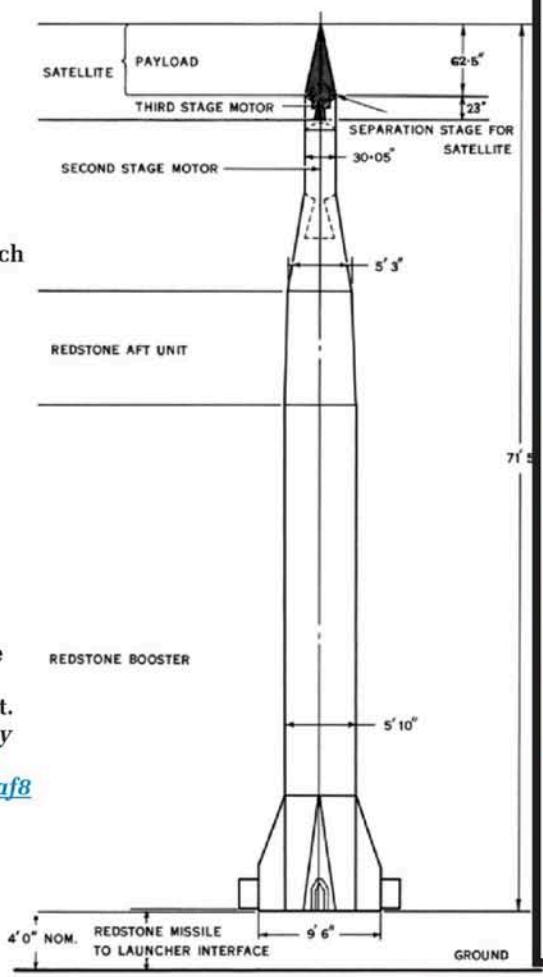
entific achievement, demonstrating a remarkable advance by Australia".

A notable message from Hubert Humphrey, Vice President of the United States reads "Word that your scientific spacecraft is performing successfully in orbit is a source of satisfaction to all. Congratulations and welcome to the 'Space Club'."

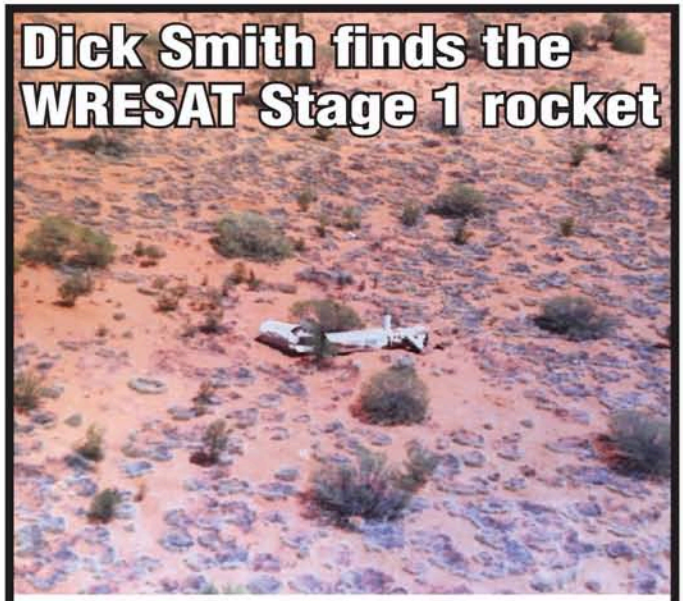
A summary of congratulations received from around the world appears at siliconchip.com.au/link/aafa

Scientific findings and conclusion

The findings of WRESAT were published in three sci-



Redstone launch vehicle and WRESAT payload. Overall height was almost 21.8m (all dimensions shown here are in feet and inches). Note that the third stage intentionally remained attached to the satellite after motor burn out. *Image courtesy of* siliconchip.com.au/link/aaf8



In 1989, Dick Smith was reading about the history of the Woomera Range and was inspired to find the remains of the rocket that launched WRESAT.

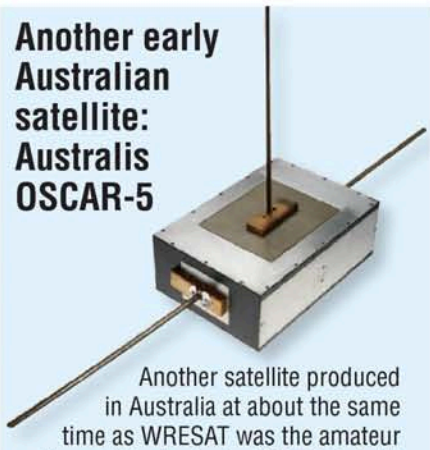
With the cooperation of the Department of Defence, he contacted the Range Safety Officer at Woomera, Bruce Henderson, who used original tracking data from the launch to determine the probable location of the first stage.

The location was predicted to be 623km north of Woomera and 255km west of Birdsville with an error range of 8km. Dick Smith mounted an expedition to find the remains of the launch vehicle and he found it in the Simpson Desert on the 5th of October.

It was recovered by volunteers in April 1990 and returned to Woomera, 600km away. The story of the recovery is very interesting itself and details are to be found in the article by Kerrie Dougherty, listed on page 24.

Dick Smith's wife, Pip, with the wreckage of the WRESAT first stage. Note how where the white paint has weathered off, it has exposed the original US Army colour scheme. Fortunately, the wreck had not been found by souvenir hunters or there might not have been much left! It was returned to Woomera, where it is now on display. *Photos courtesy Dick Smith.*

Another early Australian satellite: Australis OSCAR-5



Another satellite produced in Australia at about the same time as WRESAT was the amateur radio satellite Australis-OSCAR 5, built by students at the University of Melbourne. (OSCAR stood for Orbiting Satellite Carrying Amateur Radio).

The satellite was completed on June 1, 1967, pre-dating WRESAT, but it required some minor modifications and was finally launched on January 23, 1970 from Vandenberg Air Force Base in California.

The satellite was 43cm x 30cm x 15cm in size and weighed 17.7kg. It was the first remotely controlled amateur satellite and the first launched by the new AMSAT organisation.

See the following links for more details: siliconchip.com.au/link/aafb (the most detailed site) siliconchip.com.au/link/aafc

Here is a recording of some of its telemetry: siliconchip.com.au/link/aafd

entific papers plus a doctoral thesis. One of the findings was a confirmation of a layer of ozone in the atmosphere between 110km and 120km altitude.

Another was a refined figure for the temperature of the Sun's atmosphere which is close to the currently accepted figure.

Unfortunately, since the early days when Australia had quite an extensive involvement in space exploration, we have subsequently failed to follow up on numerous space-related opportunities.

WRESAT could have been the start of a productive space industry in Australia but unfortunately, that was not to be. SC

Recommended videos and other resources

Recollections of Professor John H. Carver on the WRESAT project can be found on pages 87 & 88 of "*Space Australia: The Story of Australia's Involvement in Space*" by Kerrie Dougherty and Matthew James, 1993. Available from the Museum of Applied Arts & Sciences, http://siliconchip.com.au/link/aag1; (Powerhouse Publishing), $32.95 plus p&p

There is information about WRESAT and other early Australian involvement in the space program at the Honeysuckle Creek website. See siliconchip.com.au/link/aag0 A scan of the original booklet published about WRESAT is also available there.

"Weapons Research Establishment Satellite (WRESAT)", 1967: siliconchip.com.au/link/aafe

At 1:35 in this video, you will see the recovered first stage of the WRESAT launch which was found by Dick Smith: siliconchip.com.au/link/aafy

Unfortunately, YouTube has removed the audio from this video due to copyright reasons but you can still see some interesting scenes, albeit silent ones. *"Woomera Rocket Range":* siliconchip.com.au/link/aaff

This video is not directly related to WRESAT but talks about the Island Lagoon Tracking Station at Woomera that received the first images from lunar orbiters that were used to select landing sites for the Apollo missions. It shows how heavily involved Australia was in the early space race. *"How Woomera helped to map the moon":* siliconchip.com.au/link/aafg See also: siliconchip.com.au/link/aafh

"A small scientific satellite" siliconchip.com.au/link/aafi

"Preparation of the satellite" siliconchip.com.au/link/aafj

"Launch of the satellite" siliconchip.com.au/link/aafk

User "mendahu" on imgur.com has created some graphic reconstructions of aspects of the launch at siliconchip.com.au/link/aafl

A biography of Professor John H Carver which also discusses his work on WRESAT: siliconchip.com.au/link/aafm

Australian Space History by Colin Mackellar, including WRESAT: siliconchip.com.au/link/aaf8

Re-connecting veterans of WRESAT: siliconchip.com.au/link/aafn and siliconchip.com.au/link/aafo

"Old Reliable: The story of the Redstone" with mention of WRESAT: siliconchip.com.au/link/aafp

There is a project to build a replica of WRESAT and its rocket, however, the crowd funding link does not appear to be working: siliconchip.com.au/link/aafq

There is a display of one of the WRESAT test satellites at the Woomera Heritage Centre. This is a picture of the display. You can see various pictures of the displays, including two of WRESAT at the following link: siliconchip.com.au/link/aafr

Australia's space-related contributions to the International Geophysical Year 1957-58, from page 29 to 32: siliconchip.com.au/link/aafs

"Retrieving Woomera's heritage: recovering lost examples of the material culture of Australian space activities" by Kerrie Dougherty: siliconchip.com.au/link/aaft

For a detailed look at the Redstone missile, go to siliconchip.com.au/link/aafu There are some excellent diagrams and detailed photos.

Redstone missile history and firing procedure: siliconchip.com.au/link/aafv

Detailed description and US Army manuals for Redstone missile: siliconchip.com.au/link/aafw

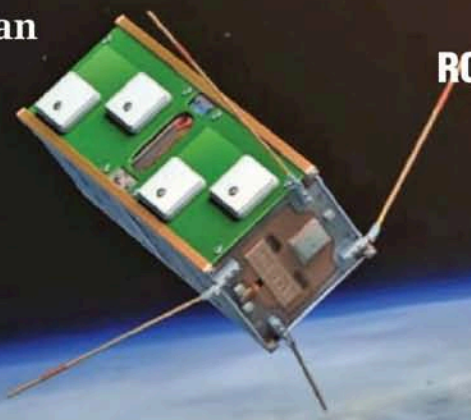
"Redstone: The Missile That Launched America into Space": siliconchip.com.au/link/aafx

**** These Silicon Chip Shortlinks will take you direct to the appropriate page***

And in 2017, Australia re-joins the Space Race . . . albeit with a hiccup or two!

Three tiny satellites, built by Australian university students, were meant to enter orbit last April. But no sooner than they were they deployed from the International Space Station, they disappeared! Tracking them down (or at least two of the three) is a story of high-tech detective work and international co-operation.

by ROSS TESTER



An artist's impression of the UNSW EC0 Cubesat leaving the International Space Station. *(Courtesy UNSW)*

At 1am Sydney time on Tuesday 19 April, a NASA mission to resupply the International Space Station (ISS) blasted off aboard an Atlas 5 rocket from Cape Caneveral, USA.

Along with sustenance for the ISS personnel, part of the cargo included 36 tiny satellites called "Cubesats". Each is about the size of a shoe box and weighs less than 2kg.

Their purpose was to carry out the most extensive measurements ever undertaken of the thermosphere, a region between 200 and 380km above Earth.

This poorly-studied and usually inaccessible zone helps shield Earth from cosmic rays and solar radiation, and is vital for communications and weather formation.

(SILICON CHIP has published two articles on Cubesats and their even smaller cousins; "*Reach for the Sky*" in March 2015 www.siliconchip.com.au/Article/8398 and "*Controlling a miniature satellite*" in February 2014 www.siliconchip.com.au/Article/6126).

Australian Cubesats

Three of the Cubesats were built by students from Australian Universities: UNSW-EC0, built by UNSW's Australian Centre for Space Engineering Research (ACSER); INSPIRE-2, by the University of Sydney, UNSW and the Australian National University; and SuSAT, by the University of Adelaide and the University of South Australia.

Deployment from the ISS went completely as planned . . except for one tiny detail. The three Australian Cubesats – along with several others – had simply disappeared!

Within 30 minutes of deployment from the ISS, they were meant to transmit a beacon. But no signal was detected by the ground teams at UNSW's Australian Centre for Space Engineering Research (ACSER) or the ANU when the Cubesats flew over Sydney, which they were supposed to do twice a day.

Flat batteries?

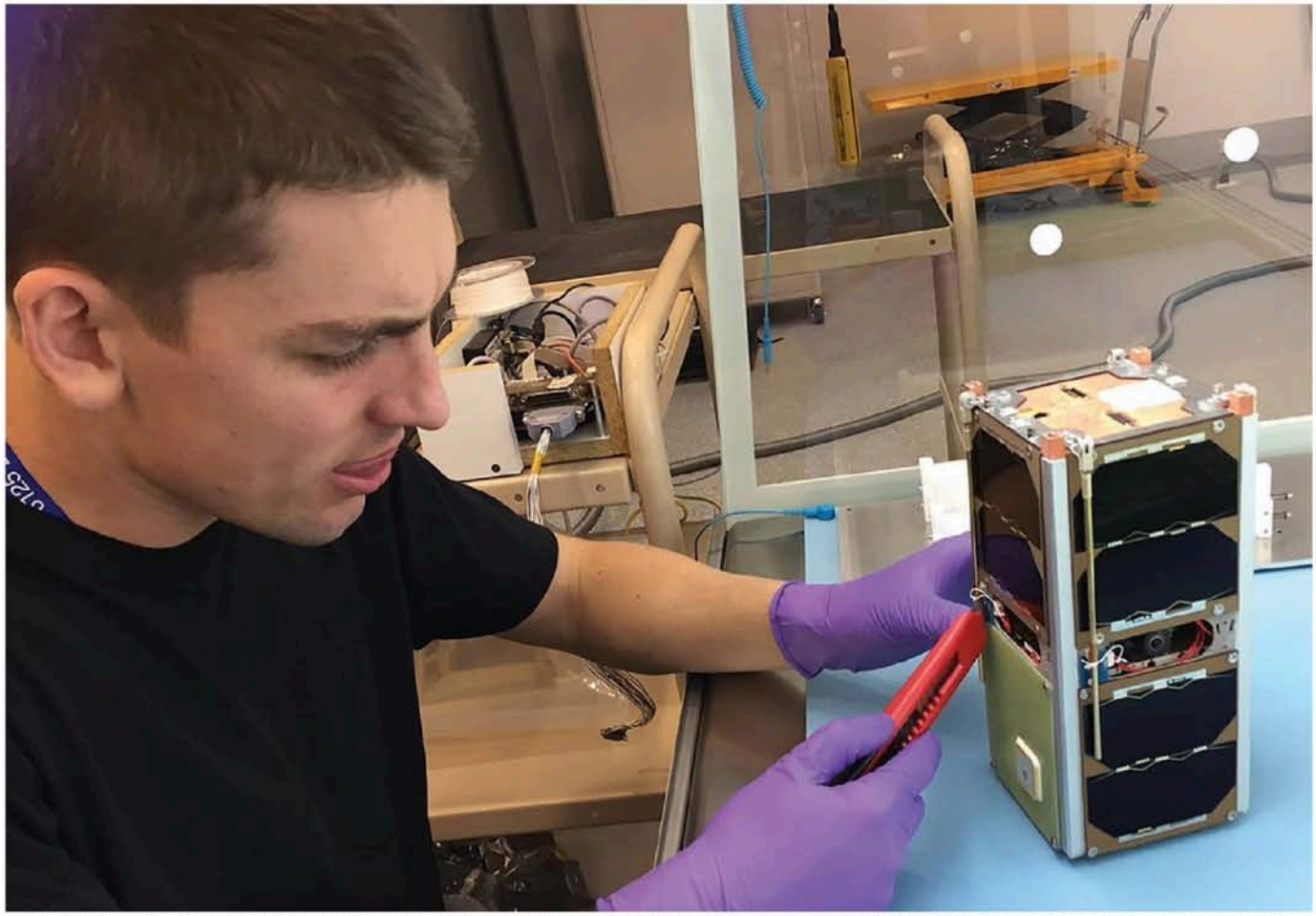
The ACSER team began to suspect the Cubesats' batteries might be to blame. In the nine months since both Cubesats had been dispatched to Europe for testing, and eventually to the US for launch, they might have lost partial charge: enough that they were now unable to extend the antennas.

With their antennas stowed, their beacons would then be too weak for the UNSW or ANU ground stations to detect.

"If batteries were the issue, the satellites have solar panels and should have been able to recharge," said Joon Wayn Cheong, a research associate at UNSW and technical lead for both Cubesats. "But that would have taken just one or two orbits. Yet, after almost a week, we still heard nothing. Clearly, something else was wrong."

"It was like something out of Apollo 13," said Elias Aboutanios, project leader for UNSW-EC0, the first Australian-built satellite in 15 years to go into space.

"Our satellite was orbiting at 27,000km/h almost 400km



Ben Southwell, from UNSW, putting the finishing touches to their Cubesat, UNSW-EC0, before it was shipped overseas for testing. It was launched aboard an Atlas 5 rocket from Cape Canaveral, bound for the International Space Station and then deployment into Earth orbit. It gives an excellent idea of the "huge size" of Cubesats!

above our heads. We couldn't see it, couldn't inspect it, and had almost no data to work with."

The engineers theorised that the satellites might be trapped in a vicious discharge/recharge loop: they didn't have enough power to extend antennas but could not recharge completely because they were repeatedly trying to deploy antennas and stabilise orientation, draining the batteries again and again.

So the ACSER team wrote software commands telling the Cubesats to power down and wait until being fully recharged before deploying antennas.

But before the commands could be sent, the engineers needed to find more powerful transmitters that the satellites – operating with stowed antennas – could "hear".

Aboutanios, who is deputy director of ACSER, reached out to the Defence Department, Optus, the CSIRO and NASA but no equipment was immediately available or could broadcast on the right frequencies. Meanwhile Cheong, who has an amateur radio licence, contacted his worldwide network.

That's when Jan van Muijlwijk came to the rescue. The sound technician near Groningen, in the Netherlands, had access to the Dwingeloo radio telescope, a restored 25-metre dish from the 1950s that was once used for astronomy and is now run by amateur astronomers and amateur radio enthusiasts.

Problem was, van Muijlwijk could only help on weekends, which meant a tense wait.

One down, two to go!

On the first attempt, on Saturday 10 June, the Dwingeloo dish detected a weak signal from INSPIRE-2, and immediately uplinked the new commands. But when the Dutchman pointed the dish at UNSW-EC0, there was only silence.

On INSPIRE-2's next orbital pass, at midnight on Sunday 11 June, a clear beacon was detected by the Dwingeloo dish in the Netherlands and by former UNSW engineer Barnaby Osborne, now at the International Space University in France, and later by INSPIRE-2 team member Dimitrios Tsifakis at ANU, along with ham radio operators in Spain, the US and Australia.

ACSER's team at UNSW, who had managed the ground segment for the INSPIRE-2 project, were elated. But also stumped. Why was UNSW-EC0 still silent? Had they identified its problem, or was something else wrong? Had some other component failed? Would they ever be able to contact the satellite?

Aboutanios, Cheong and their UNSW colleagues – Ben Southwell, William Andrew, John Lam, Luyang Li and Timothy Guo – regrouped to review what they knew, and work through more scenarios. They also looped in Osborne in France and Tsifakis in Canberra.

To find 'Echo' – as they now dubbed their satellite – the team had relied on positioning data from NORAD (North

American Aerospace Defence Command), which tracks and catalogs objects orbiting Earth.

The Cubesats had been shot out of the ISS in threes, and NORAD had detected this. It had then waited for the three Cubesats to drift apart enough that they could be tagged with their names and positions.

But what if NORAD had mislabelled UNSW-EC0?

Could they be listening for – and transmitting commands to – the wrong satellite?

They went back through the NORAD data and identified the other two satellites deployed at the same time – Nanjing University's NJUST-1 and University of Colorado's Challenger – then asked van Muijlwijk to point his dish at the other two Cubesats and listen for UNSW-EC0's beacon from those instead.

Success for another

"As soon as the Dwingeloo dish pointed to what the NORAD data said was the Challenger Cubesat, it detected a weak signal that was clearly from UNSW-EC0," recounted Cheong. "So they fired off the reset commands. And on the very next orbital pass, they received a beautiful, clear signal from UNSW-EC0."

Aboutanios mused: "For more than three weeks, we were looking in the wrong part of the sky for our satellite – we couldn't have known that."

"But the procedures we put in place, the scenarios we ran and the solutions we developed, they all paid off. You could say we succeeded by engineering the heck out of this."

University of Sydney's Iver Cairns, leader of INSPIRE-2 team, said it had been an agonising experience. "It was intensely frustrating, and surprising, to hear nothing from INSPIRE-2 or UNSW-EC0, since both are very robust satellites that passed their pre-flight tests with flying colours".

"But the recovery effort, led by our UNSW and ACSER colleagues, was a real international team effort, and something we should all be very proud of."

UNSW-EC0 and INSPIRE-2 now join the 20 other QB50 satellites successfully contacted so far.

They were joined on Friday 23 June by another eight QB50 Cubesats, launched into orbit by India's Polar rocket from the Satish Dhawan Space Centre north of Chennai.

Still no SuSAT

Of the 28 QB50 Cubesats originally deployed from the ISS in May, eight have still not been heard from – including Australia's third Cubesat, SuSAT. "We've contacted our colleagues in Adelaide to see if we can help," added Aboutanios.

The two recovered Australian satellites are now going through a long testing process leading to their commissioning. Later this year, they will join other active QB50 satellites in collecting scientific data.

The three research Cubesats are the first Australian satellites to go into space in 15 years; there have only been two before: WRESAT in 1967 and Fedsat in 2002.

"We've got more hardware in space today than Australia's had in its history," said Andrew Dempster, director of ACSER and a member of the advisory council of the Space Industry Association of Australia.

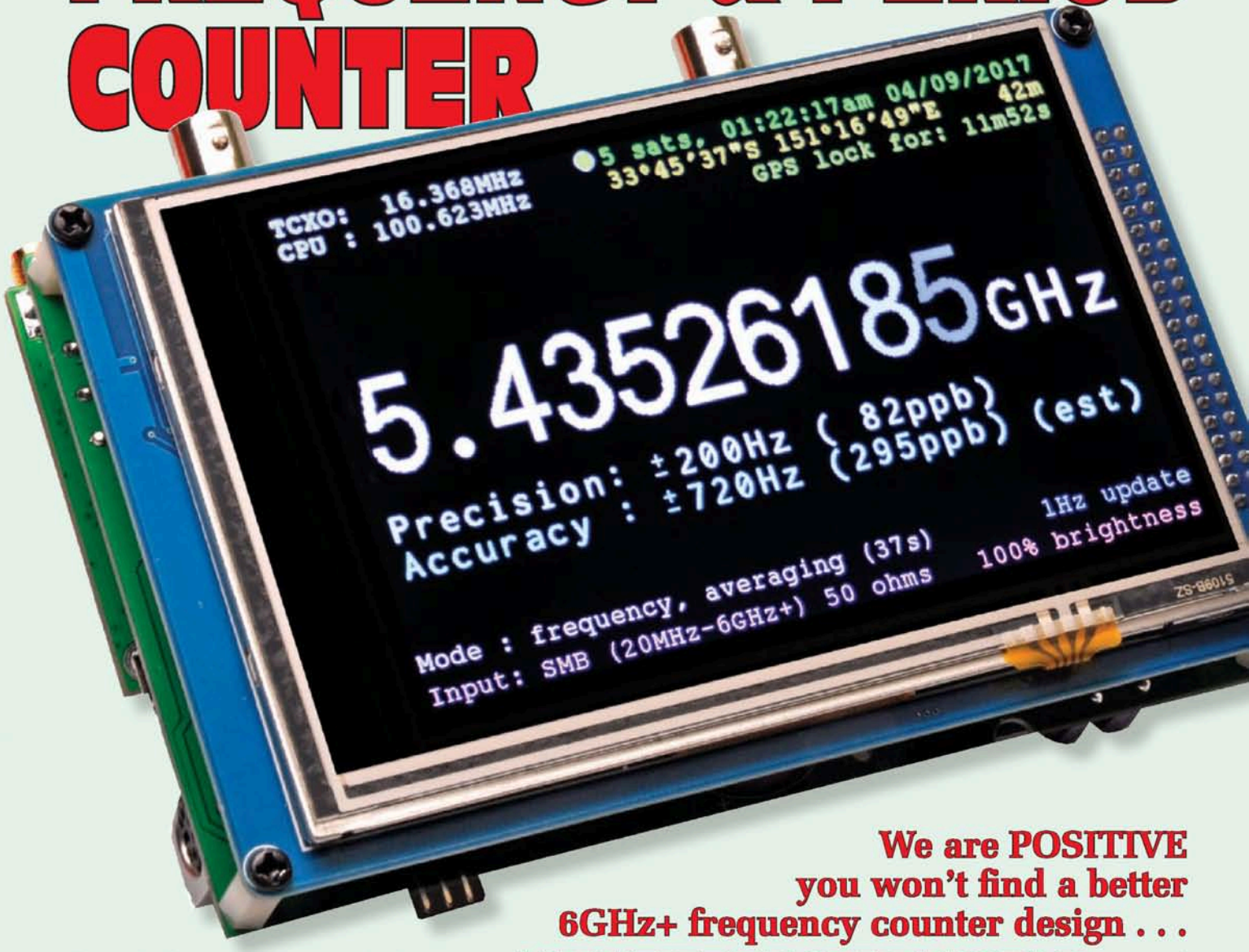
"The QB50 mission shows what we can do in Australia in the new world of 'Space 2.0', where the big expensive agency-driven satellites are being replaced by disruptive low-cost access to space." SC

UNSW student John Lam at VKI Headquarters in Delft, Netherlands, preparing the UNSW-EC0 satellite for final integration and then shipping to the USA for inclusion in the ISS-bound cargo.

World-first build-it-yourself design with 5-inch screen!

6GHz+ TOUCHSCREEN FREQUENCY & PERIOD COUNTER

by Nicholas Vinen



The "naked" counter (ie, not yet fitted into its laser-cut Acrylic case) is shown here larger-than-life-size for clarity – the actual display size is 120mm wide x 77mm high.

We are POSITIVE you won't find a better 6GHz+ frequency counter design . . . ANYWHERE IN THE WORLD or at ANYTHING LIKE THE VALUE!

Check out the features and specifications below and tell us if we're wrong! We haven't seen the equal of this all-new 6GHz (actually 6GHz+) design anywhere – built up or build-it-yourself. It's based on the famous Micromite Plus Explore 100 module to give you a superbly easy-to-read display along with TOUCHSCREEN CONTROL – and even has an optional GPS module to give you even more amazing accuracy! This is one design that we are obviously very proud of – just as you will be when you build it!

This new design completely supersedes the 2.5GHz, 12-digit Frequency Counter we described in the December 2012 and January 2013 issues (www.siliconchip.com.au/Series/21). That was a great performer for its time and has been very popular, with many built.

But this new counter is not just better – it's dramatically better!

It has greatly improved performance – for a start, it has more than twice the maximum frequency of the earlier design and a much lower minimum frequency.

And instead of a row of LED displays, we also made the jump to using a large, touchscreen LCD. It not only shows the frequency/period display but all the user controls are now ON SCREEN – no more searching for the right pushbuttons!

The touchscreen functions are provided by a **Micromite Plus Explore 100 module**, designed by Geoff Graham and Graeme Rixon and described in the September and October 2016 issues (www.siliconchip.com.au/Series/304).

Parts were getting hard to find, too

We realised the time to update the old design had come, not just because some of the parts used are becoming difficult to source – and it's a bit of a monster, needing a large instrument case and spread across two large PCBs including 26 ICs.

The December 2012 Frequency Counter had selectable gating periods of one, 10, 100 or 1000 seconds. These correspond to its update rate with the longer periods giving greater resolution. It was a bit tedious waiting for 1000 seconds (about 17 minutes) to get a reading but that's necessary if you want 1Hz resolution at frequencies over 1GHz.

This new design can provide similar resolution at around 10 digits, however, because more of the actual frequency counting is done in software (on the more powerful PIC32 processor), it will give much faster display updates.

Incidentally, we didn't think there was much point going to 12 digits because you would need a time source accurate to within one part per *trillion* to have any confidence in the result and even with GPS disciplining, that's unrealistic.

This new design can also handle much lower frequencies/longer periods than its predecessor, down to around 0.01Hz (10mHz) compared to 10Hz.

It's also more sensitive, able to operate with signals down to just millivolts, over much of its frequency range.

The display will show the applied frequency almost immediately, with an indication of the reading precision, and the reading will then be progressively refined, reflected in a slowly improving precision figures over a few minutes.

So you don't need to wait for 17 minutes to get a reading; you just need to wait until the indicated precision is good enough for your situation and then make a note of the reading.

If you don't need extreme precision, you can choose a faster update rate, with the reading changing several times per second.

High precision is great but you also need good accuracy in this sort of instrument; briefly, precision indicates the repeatability of a measurement while accuracy indicates how closely it relates to reality.

Temperature-compensated crystal oscillator plus GPS option!

We're using a temperature-compensated crystal oscillator (TCXO) frequency reference to provide good accuracy

Outstanding Features and Specifications . . .

Display: 800 x 480 pixel, 24-bit colour LCD with adjustable backlight brightness

Frequency ranges: 10mHz-50MHz (low frequency input), 6MHz-6GHz+ (high frequency input); typically counts up to 7GHz

Sensitivity: typically <10mV RMS below 3.5GHz and <125mV RMS, 3.5-7GHz

Resolution: normally seven digits, increasing to 10 after 10 minutes with long-term averaging enabled

Accuracy: ±2.5ppm initial tolerance (±0.00025% or ~5.5 digits) +1ppm/year; better with GPS unit after automatic calibration

Input impedance: selectable, 75Ω or 1MΩ (low-frequency input), fixed, 50Ω (high-frequency input)

Update rate: selectable, 1-5Hz

Modes: frequency or period with either constant updates or long-term averaging

TTL reference output: selectable, 1Hz/1kHz reference frequencies or measured frequency divided by 1000

Power: 6V DC 1A plugpack OR can operate from 5V DC (eg USB) supply or computer output for use in field

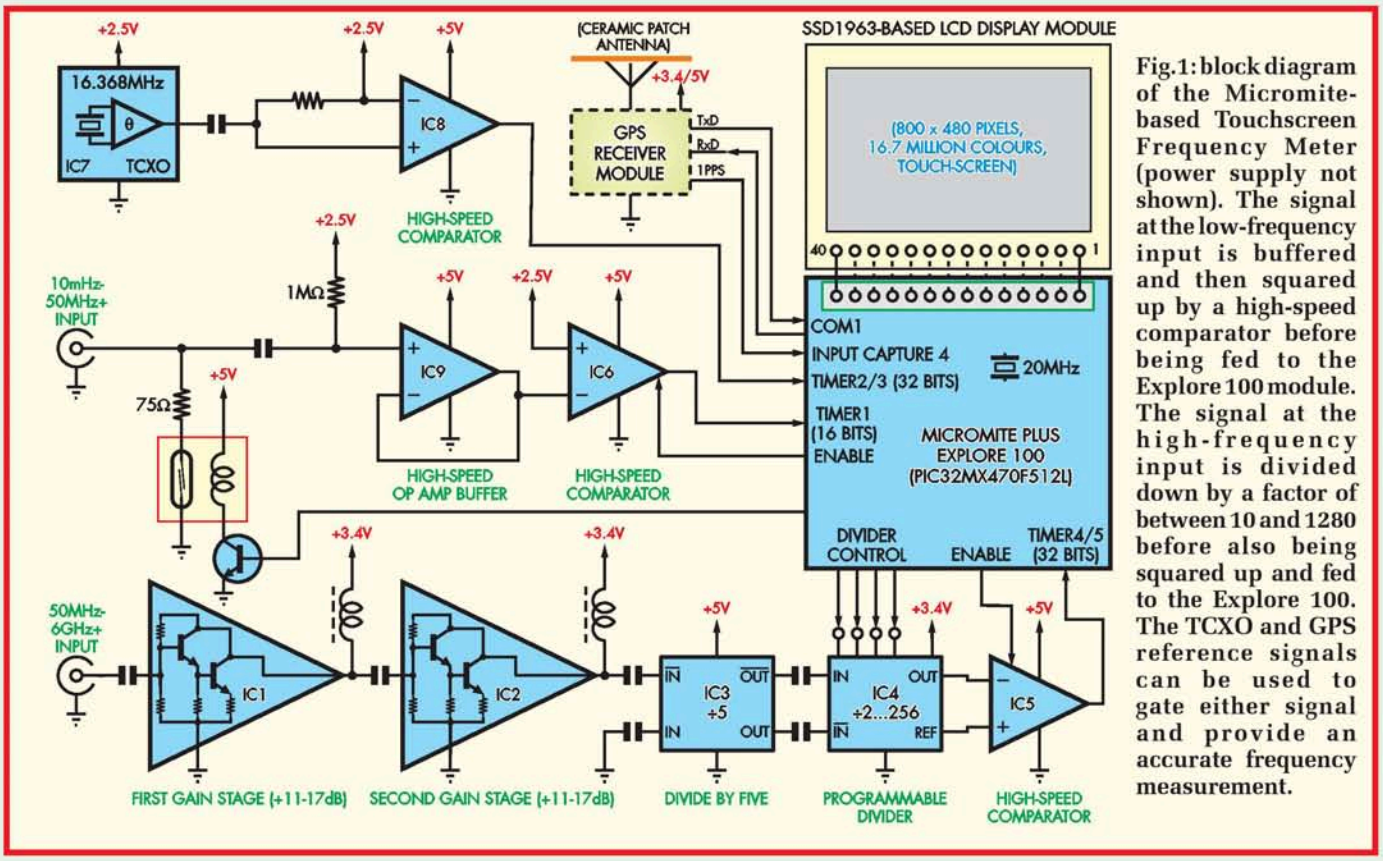


Fig.1: block diagram of the Micromite-based Touchscreen Frequency Meter (power supply not shown). The signal at the low-frequency input is buffered and then squared up by a high-speed comparator before being fed to the Explore 100 module. The signal at the high-frequency input is divided down by a factor of between 10 and 1280 before also being squared up and fed to the Explore 100. The TCXO and GPS reference signals can be used to gate either signal and provide an accurate frequency measurement.

"out-of-the-box", with the option of GPS-disciplining to give even better long-term results.

Overall operating concept

This new frequency counter features the 6GHz+ Prescaler that we published in the May 2017 issue (www.siliconchip.com.au/Article/10632). This provides the high frequency input and it has a separate input to handle the lower frequencies.

The Frequency Counter block diagram is shown in Fig.1 and gives the basic layout, showing how it is able to accurately measure the frequency of either of the inputs, shown at left.

The low-frequency input can handle signals of 0.01Hz-50MHz with a sensitivity of around 1mV RMS and a switchable load impedance of either 1MΩ or 75Ω, switched by the reed relay and transistor, as shown in Fig.1. The high-frequency input can handle signals of around 20MHz-6GHz, with a sensitivity of a few millivolts and a load impedance of 50Ω.

The low-frequency signal is buffered by high-speed op amp IC9 and then amplified and squared up by high-speed comparator IC6. The output of IC6 is then fed to the timer 1 clock input pin on the Explore 100 module. The PIC32 has five internal 16-bit timers, with timers 2/3 and 4/5 able to be paired up to form 32-bit timers.

We're using timer 1 in this case because it's asynchronous (ie, operates independently from the PIC32's own oscillator) and so can handle signals up to about 50MHz. The other times can only operate up to about 18MHz (according to the data sheet). Note that the Micromite also has an output pin which can enable or disable the output of IC6; this will become important later.

The high-frequency input is fed to two wide-band monolithic microwave amplifier ICs (MMICs), IC1 and IC2, connected in series for extra gain. The amplified signal then passes to a high-frequency divide-by-five stage (IC3) and into a programmable divider with a division ratio of between 2 and 256 before also being squared up and fed to the timer 4/5 clock input pin of the Explore 100.

The combination of the two dividers gives an overall division ratio of 10-1280, controlled by eight digital outputs from the Explore 100 module. Thus, the Explore 100 can set the division ratio fairly high for high-frequency signals, eg, 6GHz÷512, or 11.718MHz , while using a lower division ratio for lower frequency signals, to give better resolution and/or faster updates.

As with IC6, the output of IC5 can be enabled or disabled by the Explore 100 via one of its digital outputs.

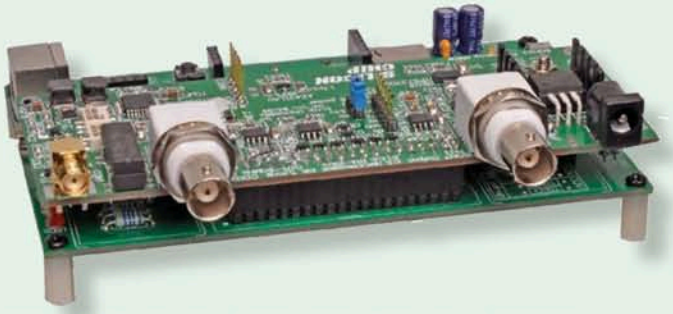
So the Explore 100 can measure the pulses resulting from either input but it needs a precise measurement interval in order to accurately calculate and display the frequency. Its internal 100MHz clock runs off a PLL (phase-locked loop) which is driven by a 20MHz crystal and internal oscillator amplifier.

But this won't be *exactly* 20MHz and will change with temperature and over time.

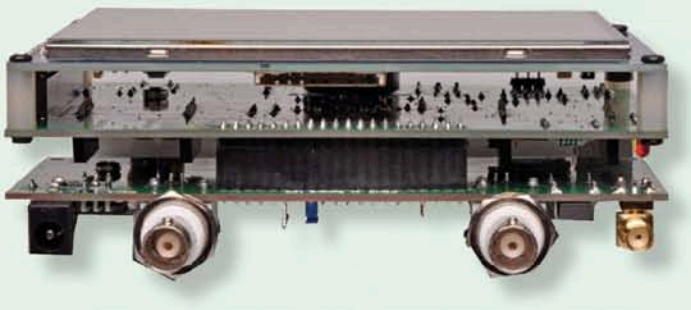
Reference frequencies

To solve this, we are using a more accurate 16.368MHz TCXO (Temperature-Controlled Crystal Oscillator), IC7, as the frequency reference. Unfortunately, because the Explore 100 is a pre-built module, we can't use this to drive the main clock, at least, not without butchering the board.

Instead, we square up the output of this oscillator (it's a sinewave) using IC8 and feed this to the clock input for



This "upside-down" photo shows how the frequency counter PCBs assemble one on top of the other. The I/O connectors are on the opposite side of the Explore 100 board than the touchscreen . . .



. . . as shown in this photo of the completed unit, with the LCD display module mounted on stand-offs. Because of this arrangement, the input and output connectors are along the top of the module.

timer 4/5. Not only does this give us an accurate time reference but we can use two of the PIC32's "output compare" units (OC1 and OC2) to automatically gate the outputs of IC5 and IC6 for a precise number of pulses from IC8.

For example, if we reset timers 1-3 and then set the output compare unit to drive the enable pin low (on) for 1,638,400 pulses of timer 4/5, we can measure exactly 100ms worth of pulses from both inputs.

The TCXO is quite stable and precise, with an initial tolerance of ±2.0ppm and only ±0.5ppm variation from -10°C to +70°C and ±1.0ppm drift per year.

This translates to an initial accuracy of around ±0.00025% and a long-term accuracy of around ±0.001%.

Say you are measuring a signal of exactly 2.4GHz. That means you should get an initial measurement of between 2,399,994,000Hz and 2,400,006,000Hz. If you have a very precise reference frequency to calibrate the unit (essentially, allowing you to measure the actual frequency of the TCXO and then compensate for it), you could probably get it to within a few hertz.

That's pretty good but what if you don't have a precise reference frequency and what about temperature variations and drift over time? Well, with the addition of a low-cost GPS module, the TCXO can be automatically calibrated (disciplined).

Its 1PPS input is connected to the Input Capture 4 pin, which automatically stores a copy of the contents of the timer 2/3 counter each time it goes high. We can then extend this to a 64-bit value in software and keep, say, 3600 values, or one hour's worth of GPS 1PPS timestamps.

The individual intervals between GPS 1PPS pulses are not necessarily precise but averaged over the long term, they should give us a very good reference.

So if we calculate the difference between the TCXO counter value one hour ago versus the most recent pulses and divide the result by 3600, that gives us the exact TCXO frequency, averaged over the last hour, to within one or two hertz.

So the upshot is that if you fit the counter with a GPS module, provided it is getting enough signal from the satellites to get a good lock, you should get very accurate readings without needing to do any calibration.

The software can save the calibration value into flash memory so that even if you only power up the counter for a short time (eg, to make a measurement), it can be reasonably accurate. You just need to leave it powered up for a while every now and then to let it adjust its own calibration.

By connecting up the GPS unit's serial console to communication port 1 on the Explore 100, we can check whether it has a proper satellite lock before using the 1PPS signal and we can also display information on the LCD, such as the number of satellites in view, UTC time/date and the current location (latitude/longitude/altitude).

Frequency display

But of course the job of the Frequency Counter is to display the frequency of the currently selected input and you can use the touchscreen to select the input you want to measure and the measurement period.

The software then sets up the timers appropriately and continuously measures, computes and displays the result in large letters on the LCD. It can even format the result it into a nice, human readable value like "2.38754GHz" or "434.56MHz".

The Explore 100 can tell whether you have a GPS unit attached by monitoring the serial port. If you do, it will automatically perform long-term TCXO calibration and use the calibrated value when measuring the input frequencies. Otherwise, it will either use the default TCXO frequency (16.368MHz) as the reference, or a calibrated value, if you program one in. It can also show the frequency reading as a period value instead. That is most useful for lower frequencies. It's just a matter of inverting the calculations.

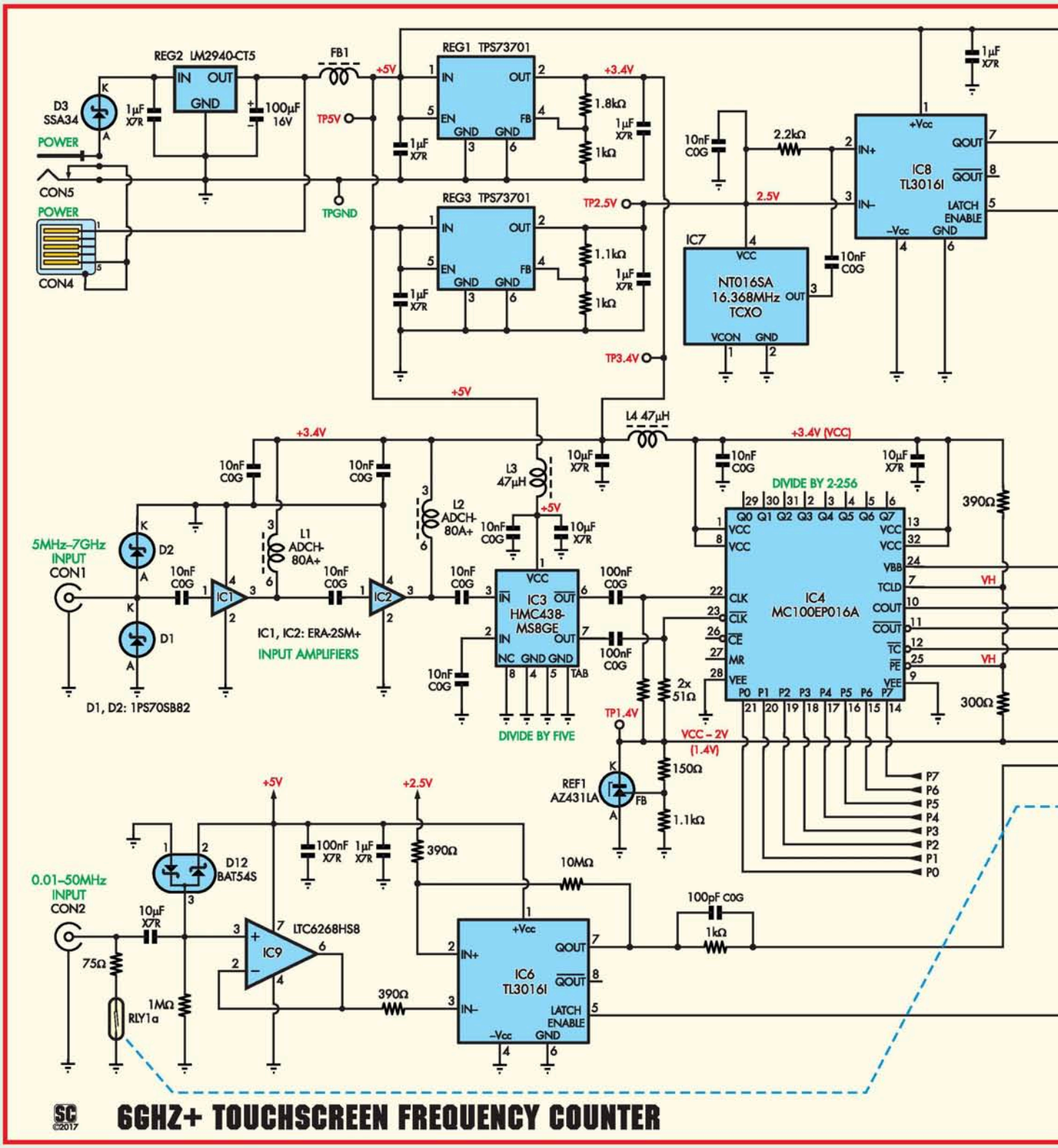
Circuit description

Fig.2 shows the complete circuit, minus the Explore 100 itself, which plugs in via 40-pin DIL connector CON3. The Frequency Meter plugs into the top side of the Explore 100 PCB, with the input, output and power connectors accessible via the top edge while the 5-inch LCD touchscreen is mounted on the opposite side of the Explore 100.

Most of this circuit corresponds to the block diagram of Fig.1, except for the power supply, which was not shown. Starting with the low-frequency (50MHz) input, this is fed in via BNC connector CON2. When set for a 75Ω input impedance, this is simply achieved by reed relay RLY1 connecting a 75Ω termination resistor across the socket.

The signal is AC-coupled with a 10µF ceramic capacitor and biased to 2.5V using a 1MΩ resistor. Thus, with RLY1 de-energised, the input impedance is around 1MΩ although there is no DC path to ground. A dual series schottky diode, D12, clamps the signal so that it is between -0.2V and +5.2V. It is then fed to the pin 3 non-inverting input of buffer op amp IC9.

This is a Linear Technology LTC6268HS8 which has a -3dB bandwidth of 350MHz when set for unity gain (as it



6GHZ+ TOUCHSCREEN FREQUENCY COUNTER

is here). So it will have negligible attenuation of signals below 50MHz. It has a very low input bias current of typically 3fA (yes, femtoamps – that's 0.000000000000003A!) at room temperature, which is the primary reason why we're using it here, as a buffer for IC6.

Basically, the input bias current of comparator IC6 is so high that it would cause several volts to appear across the 1MΩ bias resistor if it was connected directly to IC6's input. If we lowered the value of this 1MΩ resistor to solve the bias current issue, that would both load up the signal source and also increase the minimum frequency which could be measured. The easiest solution is to buffer the signal.

As well as having a very low input bias current, IC9 also needs a low input offset voltage as this would reduce the sensitivity of the frequency meter by causing a mismatch between the quiescent voltage at pins 2 and 3 of IC6, which normally should both be sitting very close to 2.5V, thus only a small signal from CON2 is needed to cause the out-

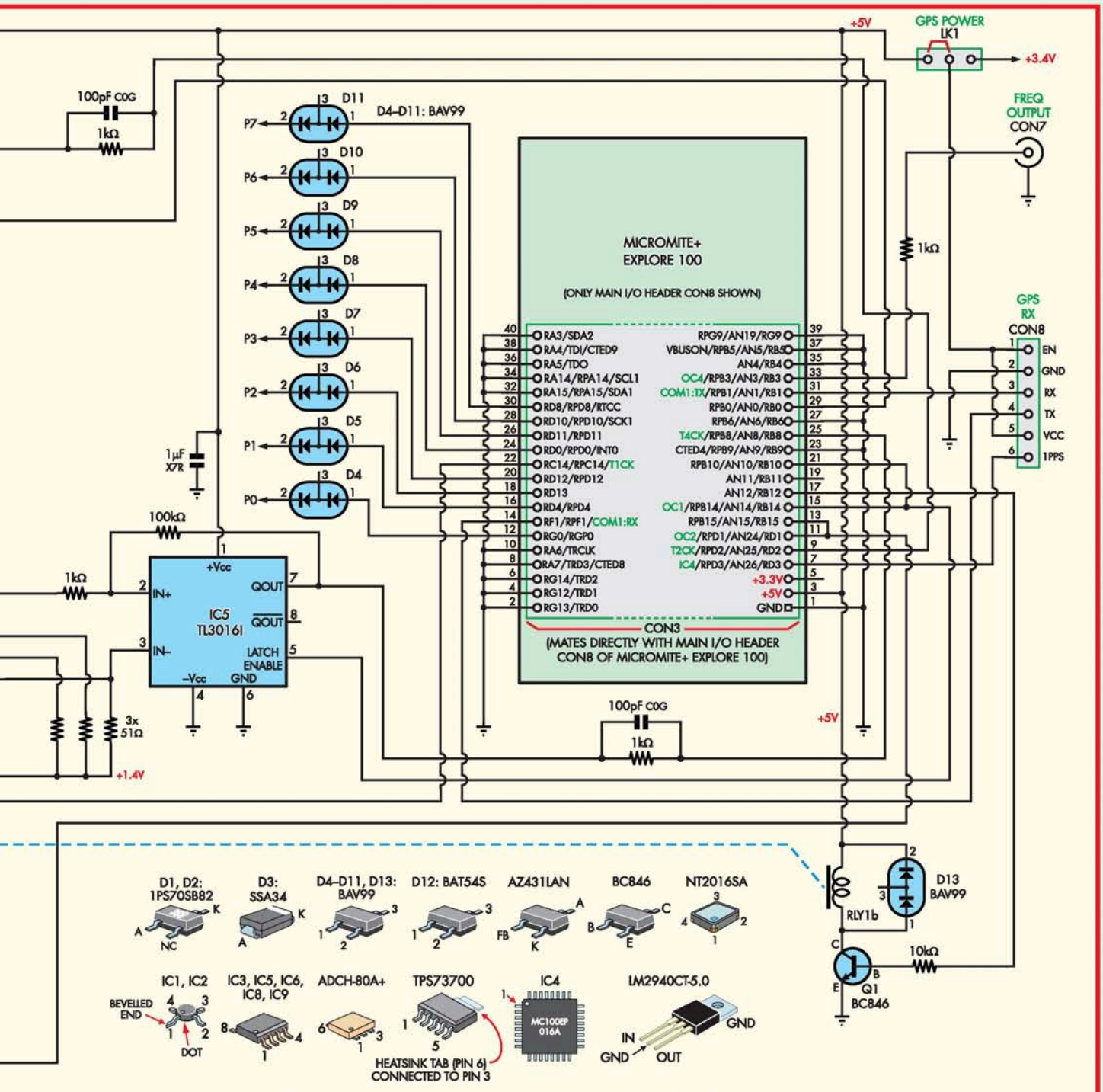


Fig.2: complete circuit for the Frequency Meter, with the Explore 100 "black box" at right. The low-frequency (up to 50MHz) input signal path is shown at lower left while higher frequency signals are fed into the configurable prescaler shown at centre left. The linear power supply is at upper left and provides 5V, 3.4V and 2.5V rails and there is also a 1.4V (3.4V - 2V) rail for ECL logic termination.

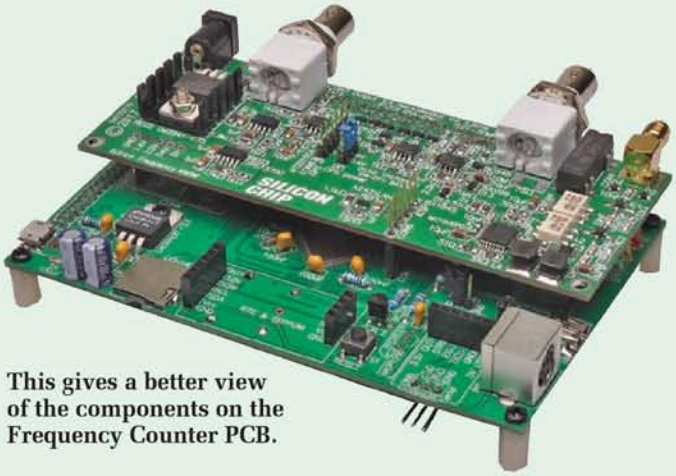
put of IC6 to toggle.

IC9 also has a low noise of 4.3nV÷√Hz, which equates to about 80µV over the quoted 350MHz unity gain bandwidth. Too much noise could cause inaccurate frequency readings because it would be superimposed on the signal and so could cause extra "zero crossings".

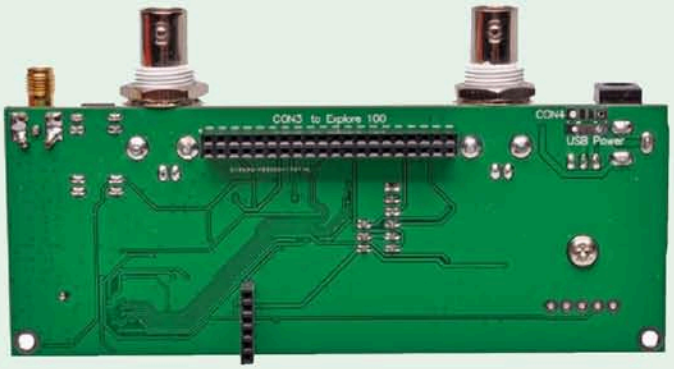
Noise at this input of IC6 is rejected by providing a small amount of hysteresis, due to the 10MΩ resistor between the pin 7 non-inverted output and pin 2 non-inverted input, combined with the 390Ω resistor from output pin 6 of IC9. Given that the output swing of IC6 is 5V, that gives a hysteresis of around 200µV (5V x 390Ω ÷ 10MΩ).

As this is higher than the noise from IC9, it should result in a zero reading with no signal applied but will hardly affect the sensitivity.

The reason for the 390Ω series resistor between IC9 and IC6 is to match the source impedance for the two inputs (pins 2 and 3) so that the bias current flowing into these



This gives a better view of the components on the Frequency Counter PCB.



The underside of the Frequency Counter PCB (the top board in the photo at left). The only "components" on this board are the 2 x 20-pin female header which mates with the plug on the lower board and the 6-pin ICSP pass-through header.

inputs will cause a similar shift across both resistors, so the error will mostly cancel out.

The output from pin 7 of IC6 is fed to pin 22 of CON3 (input RC14 [pin 74] of the PIC32) via a 1kΩ resistor with a parallel 100pF capacitor. The 1kΩ resistor is there to limit current when the output of IC6 is high since it will go up to +5V while the PIC32 only has a 3.3V supply rail. The 100pF capacitor ensures that high-frequency signals will not be significantly attenuated by the input capacitance of the PIC32 pin.

High-frequency signal path

Higher frequency signals are fed into CON1, an SMB socket. As noted above, most of the following circuitry is based on that of the 6GHz+ Prescaler from the May 2017 issue. Its circuit diagram was shown on pages 32 and 33 of that issue.

The signal is clamped to around 1V peak-to-peak by schottky diodes D1 and D2 and then AC-coupled to the input of MMIC IC1, which provides about 11-16dB gain, depending on frequency. Its input and output impedances are both matched to 50Ω.

Power supply for IC1 is fed into its pin 3 output via RF choke L1, with a snubber/Zobel network from pin 3 to ground to improve its stability and provide better sensitivity between about 4-4.5GHz.

The output signal is then fed to another, identical amplification stage based on IC2/L2, giving a total gain of around 22-32dB. The amplified signal is then AC-coupled again, via a 10nF capacitor, to the inverting input pin 3 of IC3, a 6GHz divide-by-five counter which uses high electron mobility transistor (HEMT) technology. Its non-inverting input is tied to ground with another 10nF capacitor as we are using it with a non-differential signal.

The differential output signal, at one-fifth of the input frequency, appear at output pins 6 & 7 and these signals are then AC-coupled to the differential inputs of IC4 using 100nF capacitors.

IC4 is an ECL 1.2GHz programmable counter. Its inputs are terminated to a supply rail 2V below its V_{CC} pin via 51Ω resistors, as suggested in the data sheet.

Setting the division ratios

IC4 contains an internal 8-bit counter. Every time it exceeds 255 (11111111 in binary) to zero, the counter value is reset to the value provided externally on the P0-P7 inputs. If this pre-load value is, say, 254 then the counter will roll over on every second input pulse (254, 255, 254, 255, ...) and thus it essentially acts as a divide-by-two device. Or you could pre-load 252 and it would act as a divide-by-four, and so on.

Each of the P0-P7 inputs has an internal pull-down resistor so the PIC32 microcontroller determines the division ratio by pulling up those inputs which need to be set to one (high). This is done in each case via a BAV99 dual series diode, which drops the 3.3V high level from the PIC32 outputs to around 2.3V, a suitable high level for an ECL device.

The MC100EP016A data sheet says that with a 3.3V supply, a high level is defined as between 2.075V and 2.42V. This arrangement may seem a bit crude but it works well.

IC4 has three outputs, COUT (pin 10), $\overline{\text{COUT}}$ (pin 11) and $\overline{\text{TC}}$ (pin 12). All three are terminated to the VCC-2V (1.4V) rail via 51Ω resistors.

We found the $\overline{\text{TC}}$ output gave the cleanest waveform so we're feeding this to high-speed comparator IC5. It compares it to the reference voltage from pin 24 (V_{BB}), which is halfway between the ECL high and low thresholds. The result is a 5V square wave at output pin 7 which can then be fed to the PIC32, again with a 1kΩ series current-limiting resistor paralleled with a 100pF capacitor.

Reference oscillator

The temperature-compensated crystal oscillator (TXCO) IC7, runs from a dedicated 2.5V rail since this is what it requires and providing it with a regulated rail will minimise any frequency shift due to supply variation.

It has a 10nF bypass capacitor and its sinewave output at pin 3 (around 0.8V peak-to-peak) is AC-coupled to the non-inverting input pin 2 of comparator IC8, via another 10nF capacitor.

This signal is DC-biased to 2.5V via a 2.2kΩ resistor and the same 2.5V bias is applied to inverting pin 3 so that the square wave from pin 7 will have a duty cycle close to 50%.

The clock signal is then fed to the T2CK/RD2 pin of the PIC32 in the Explore 100, via another paralleled 1kΩ resistor and 100pF capacitor pair. The enable pin (pin 5) of IC8 is driven from the RB0 output but in practice, it's enabled pretty much all the time.

Power supply

Power normally comes from a 6V DC regulated plugpack

and the current drain is normally close to 1A. This is regulated to 5V by 1A low-dropout regulator, REG2, which has a 1µF input bypass capacitor and 100µF output filter capacitor for stability. We're using an LDO (low dropout) regulator to reduce dissipation, since it means we can have a 6V DC regulated input and still draw at least 1A without it dropping out.

It does need a small heatsink though, as it will dissipate 1W continuously, and more if the incoming supply is much above 6V. Its output passes through ferrite bead FB1, so that any high-frequency noise produced by the circuit does not get radiated out of the plugpack leads.

The 5V rail powers the Explore 100 module including the LCD touchscreen backlight, as well as high-frequency divider IC3, op amp IC9 and the reed relay, RLY1. It can also be used to power the GPS module, if required. This 5V rail is also fed to LDO adjustable regulators REG1 and REG3. These identical devices have different programming resistors so that they produce 3.4V DC and 2.5V DC regulated rails.

The 2.5V rail is for the TCXO (IC7) and is also used in a few places as a 5V half-supply reference for DC biasing the inputs of high-speed comparators IC6 & IC8. The 3.4V rail powers amplifiers IC1 and IC2, ECL divider IC4 and can also be used to power the optional GPS module. As explained earlier, REF1 derives the 1.4V rail (3.4V–2V) which is used to terminate IC4's clock inputs and its outputs.

Finally, output connector CON7 can provide a 3.3V square wave output which is fed from the RB3/OC4 pin of the PIC32 on the Explore 100 module. This can be driven by its Output Compare module, producing a PWM waveform derived from one of the timers. As such, it can be set to produce a frequency which is a fraction of one of the input frequencies, for use as a trigger or reference frequency.

Or it can provide a fixed reference frequency derived from the TCXO or a 1PPS or 1kHz reference derived from the GPS module. This is selected using the touchscreen.

Software basics

We won't go into a lot of detail here but it's helpful to understand how the software is able to perform frequency measurements using the circuit presented. In essence, we have eliminated all the house-keeping logic circuitry used the previous 12-digit frequency counter and these functions are now performed by the software.

As stated, the squared-up signal from the low-frequency input is applied to the clock input for asynchronous timer 1 (T1CK), while the 16.368MHz reference oscillator signal is applied to the timer 2/3 clock input (T2CK) and the frequency-divided signal from the high-frequency input goes to the timer 4/5 clock input (T4CK).

Since timer 1 is a 16-bit timer, with the maximum specified input frequency of 50MHz, it could roll over every 1.3ms (2^{16}÷50MHz, or 65536÷50,000,000).

That isn't too fast, and fortunately the Micromite BASIC firmware exposes the timer 1 interrupt to CFUNCTIONS. So we can set up an interrupt handler for this roll-over in C and use that to increment another 16-bit register, to form a 32-bit timer. It handles a maximum of 763 interrupts per second.

We also need to set up timer pairs 2/3 and 4/5 in a CFUNCTION. The fact that we're using all five timers in this manners means that we can't use any of MMBasic's

Parts list – 6GHz+ Touchscreen Frequency Counter

1 Micromite Explore 100 module or kit (Silicon Chip online shop Cat SC3834)
1 6V DC 1A+ regulated plugpack
1 double-sided PCB, coded 04110171, 134 x 51.5mm
1 set of laser-cut acrylic case pieces (Silicon Chip online shop Cat SC4444)
2 ADCH-80A+ RF inductors (L1,L2)
2 47µH 1A 6x6mm SMD inductors (L3,L4)
1 5V DIL reed relay (RLY1; Jaycar SY4030)
1 low-resistance SMD ferrite bead, 3216/1206 (FB1)
1 6031-type flag heatsink (for REG2)
1 M3 x 8mm machine screw and nut (for REG2)
1 PCB-mount right-angle SMD connector, 6GHz+ (CON1)
2 PCB-mount right-angle BNC connectors (CON2,CON7)
1 20x2 female header, 2.54mm pitch (CON3)
1 PCB-mount DC barrel socket, pin diameter to suit plugpack (CON5, recommended) OR
1 micro USB SMD socket with locating pins (CON4)
1 6-pin female header with long pins, 2.54mm pitch (CON6, for ICSP pass-through)
1 6-pin polarised header and matching plug, 2.54mm pitch (CON8)
1 3-pin header, 2.54mm pitch, with shorting block (LK1)
1 GPS module (eg, VK2828U7G5LF) (optional but recommended)
2 25mm long M3 tapped spacers
2 12mm long M3 tapped spacers
2 M3 x 32mm machine screws
6 M3 x 10mm machine screws
4 M3 x 6mm machine screws
8 M3 Nylon hex nuts
4 3mm ID, 6mm OD, 1mm thick Nylon washers

Semiconductors

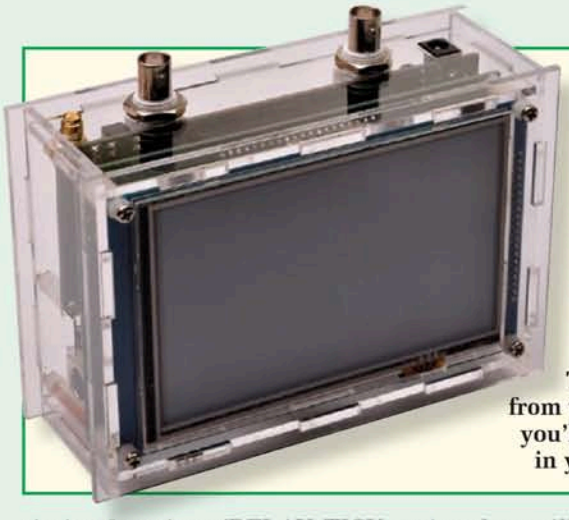
2 ERA-2SM+ SMD MMICs (IC1,IC2)
1 HMC438MS8GE, MSOP-8-PP (IC3)
1 MC100EP016A programmable ECL counter, TQFP-32 (IC4)
3 TL3016I high speed comparators, SOIC-8 (IC5,IC6,IC8)
1 NT2016SA-16.36800 SMD TCXO (IC7)
1 LTC6268HS8 500MHz op amp, SOIC-8 (IC9)
1 AZ431LAN voltage reference, SOT-23 (REF1)
2 TPS73701 adjustable LDO regulators, SOT-23-5 (REG1,REG3)
1 LM2940-CT5 LDO 5V regulator, TO-220 (REG2)
1 BC846 NPN transistor, SOT-23 (Q1)
2 1PS70SB82 UHF diodes, SOT-323 (D1,D2)
1 SSA34 3A schottky diode in DO-214AC/SMA package (or equivalent), (D3)
9 BAV99 dual series diodes, SOT-23 (D4-D11,D13)
1 BAT54S dual series schottky diode, SOT-23 (D12)

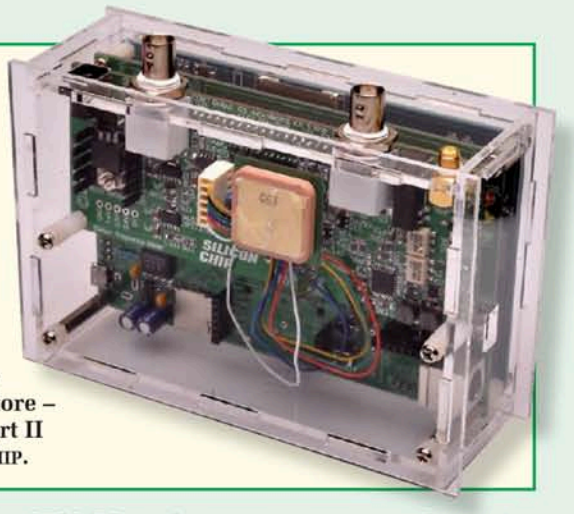
Capacitors (all SMD 3216/1206 6.3V X5R/X7R)

1 100µF 16V through-hole electrolytic
4 10µF
9 1µF
3 100nF
9 10nF 0805
5 100pF C0G/NP0 0805

Resistors (all SMD 2012/0805 1% unless noted)

1 10MΩ 1 1MΩ 1 100kΩ 1 10kΩ 1 2.2kΩ
1 1.8kΩ 2 1.1kΩ 7 1kΩ 3 390Ω 1 300Ω
1 150Ω 5 51Ω 2 33Ω 1 75Ω 1W 6432/2512 1%





Here's what the new counter will look like next month, when we put it into its purpose-designed laser-cut Acrylic case. A front cut-out gives access to the 5" touchscreen display. It's not just a sensational performer, it looks sensational too! The case will be available from the Silicon Chip Online Store – you'll find all the details in Part II in your November Silicon Chip.

timing functions (DELAY, TICK, etc) as they will no longer work properly, but we can provide our own timing functions written in C.

While we've found the synchronous timers (ie, timers 2-5) will operate OK for signals up to about 24MHz, the PIC32's specifications indicate a minimum period of 55ns which equates to 18.18MHz.

The signal driving timer 4/5, from the programmable divider, can be kept under this frequency limit by briefly measuring the input frequency using the maximum divider value of 1280, which gives a maximum frequency of under 5MHz with a 6GHz input, then computing the lowest possible divider value for that frequency to give the best resolution without exceeding the timer's limit.

For example, if the input frequency is 2.4GHz, the unit will measure 1.875MHz (2.4GHz÷1280) and it can then set the division ratio as low as 132, which gives 18.18MHz (2.4GHz÷132), just on the device's limit. In practice, a slightly higher division ratio would be used to account for measurement errors and so on.

Now, if the unit is set to measure the frequency at the 0.01Hz-50MHz input, pin 11 (RD1) will initially be set high, disabling the output pulses from IC6, while timer 1 is zeroed. RD1 will then be configured as OC2, controlled by the second Output Control unit. This compares the value of timer 2/3 to a fixed value and drives OC2 low while the timer value is below the specified value.

This allows us to set the "window" period during which timer 1 runs to a fixed period based on the frequency of the TCXO. So if we set the comparison value to 1,638,600 then timer 1 will be active for 100ms and we can determine its frequency with just some simple calculations.

Similarly, when measuring the frequency from the input with the prescaler, we can gate the output using OC1 (RB14), which also has its output state determined by the value of timer 2/3.

We do have to be careful with this one though, because we're gating the output of the prescaler, not the input. That could lead to errors in the frequency measurement, so ideally, we should measure the time between OC1 going low and the first pulse from the prescaler, and also bring OC1 low manually once counting is finished and measure the time until the next pulse.

These figures can then let us "fine tune" the measurement, to get a more accurate figure for the input frequency. The software uses the fact that RD1 (OC2) is connected to general purpose I/O pin RB15 while RB14 (OC1) is also connected to GPIO RB10. So we can set up pin change interrupts on RB14 and RB10, so that an interrupt routine is triggered when the OC1/OC2 outputs change state.

GPS-based automatic calibration

All the other tasks (updating the screen, switching the relay, etc) are handled in the BASIC code. That just leaves the unit's use of the GPS 1PPS signal to provide more accurate measurements.

We have the 1PPS output of the GPS unit connected to the RD3 I/O pin which is configured for the Input Capture function (IC4).

This automatically stores the 32-bit value in timers 2 and 3 on the rising edge of each GPS unit output pulse. The software can periodically check the input capture interrupt flag and if set, it can then retrieve this "timestamp" value and store it in a large memory array.

It's then just a matter of "crunching" the numbers in this memory array, which gives the number of TCXO pulses at one-second intervals over a long period, to calculate the actual TCXO frequency and apply this correction to frequency measurements made using its timebase. By using long-term measurements, we eliminate GPS signal jitter errors.

By the way, we mentioned earlier that we have to do our own timing in the code and we have a couple of options for doing this.

The Micromite code doesn't give us access to an interrupt for timer 2, unfortunately, so we can't generate a periodic interrupt based on its value. But we certainly can "busy wait" (or poll) based on its value to delay the code for an approximate time period.

We can also set up either timer 1 (when using timers 4/5 for measurement) or timers 4/5 (when using timer 1 for measurement) to run off the system clock and then delay based on these values. But in practice, our code can afford to block the main loop when it needs a delay so simply polling the contents of timers 2 and 3 is good enough.

Next month

That's enough to absorb for one month! Next month, we will go through the PCB assembly process, putting it together with the Explore 100 and getting the software up and running. We'll also go over testing and calibration procedures and describe fitting it into a custom-made acrylic case.

And last but not least, we'll tell you where we obtained the more esoteric components used in the counter. SC

HARE & FORBES MACHINERYHOUSE

"Setting the standard for Quality & Value"

A family owned Australian business
Established 1930

THE INDUSTRY'S CHOICE!

CNC Machinery | Metal Working | Sheet Metal Fabrication | Wood Working | Workshop & Automotive | Lifting Handling | Cutting Tools | Machine Tool Accessories | Measuring Equipment

4 Piece Measuring Kit

- 0 - 25mm Micrometer
- 150mm / 6" Rule
- 150mm / 6" Vernier
- 100 x 70mm Square

$44 ~~$54.45~~ (M012)

Digital Calipers

- Hardened S/S mechanism
- I/O glass scale system
- Metric/Imperial Settings
- Four way measurement

SIZE			
150mm/6"	$98	~~$107.80~~	(Q180)
200mm/8"	$125	~~$139.15~~	(Q181)

20-116 Outside Micrometer Set

- 4 piece set 0-4"
- Easy adjustment for recalibrating
- Carbide tipped anvils
- Resolution: 0.0001"

$165 ~~$181.50~~ (Q116)

34-213 Dial Indicator

- 0-5mm range
- Smooth 6 jewel movement
- 0.01mm graduations
- 40mm dial face
- Flat or lug back

$79 ~~$90.75~~ (Q213)

HL-35T Halogen Work Light

- 35W light
- 240V to 12V transformer
- 520mm flexible arm
- Magnetic base

$83 ~~$93.50~~ (L283)

CPP-20LT Coolant Pump & Tank

- 9 litre tank
- 20 ltrs/min. 240V pump
- Includes magnetic base nozzle & on/off switch box

$239 ~~$264~~ (P235)

CB-2 Gravity Feed Coolant System

- 2 x 1 litre plastic bottles
- Flex hose nozzle
- Flow control valve
- 2 x support brackets

$25 ~~$29.70~~ (P220)

38-435 Magnetic Base

- 80kg holding power
- 300mm reach
- V-Base for placing on round surfaces
- On/Off lever releases magnet

$66 ~~$78.65~~ (Q435)

RP7834 Air Tool Kit

- 1/2" impact gun
- 1/4" die grinder
- 3/8" ratchet wrench
- Air hammer & chisel set

$145 ~~$165~~ (A053)

Precision Boring Head Kits

- 1-1/2" x 18TPI threaded body
- Includes boring bars
- Micro adjusting screw

Model	SIZE			
BC-2K	50mm	$167	~~$187~~	(M182)
BC-3K	75mm	$215	~~$242~~	(M183)

Boring Bar Sets

- Carbide tipped boring bar
- 12mm set suits BC-2K
- 18mm set suits BC-3K

SIZE			
9 piece/12mm	$56	~~$66~~	(M180)
12 piece/18mm	$89	~~$99~~	(M181)

Boring Head Shanks

- Shanks hardened & ground
- 18TPI to fit BC-2K & BC-3K boring head kits

SIZE			
3MT x 1/2"	$69	~~$78.65~~	(M192)
NT30 x 12mm	$69	~~$78.65~~	(M193)

58 Piece Clamp Kits

- Black oxide finish, tool steel, heat treated
- Rolled threads

SLOT	STUD			
12mm	M8	$86	~~$99~~	(C0955)
14mm	M10	$86	~~$99~~	(C0965)
16mm	M12	$86	~~$99~~	(C0966)

3 Jaw Self-Centring Lathe Chucks

SIZE			
80mm	$89	~~$99~~	(C198)
100mm	$99	~~$110~~	(C200)
125mm	$112	~~$132~~	(C202)
160mm	$140	~~$165~~	(C203)

4 Jaw Independent Lathe Chuck

SIZE			
100mm	$99	~~$110.00~~	(C230)
125mm	$115	~~$126.50~~	(C232)
160mm	$125	~~$154.00~~	(C250)
200mm	$220	~~$242.00~~	(C205)

Fitting and Machining Technical Book

- Engineering trade book
- Useful facts and figures
- 640 technical pages

$80 ~~$88~~ (L341)

3-Piece Universal Milling Kit

- 12mm & 16mm end mills
- 50mm face mill
- 1 Pkt (10) of inserts

$245 ~~$275~~ (M530)

Lathe Turning Tool Kit

- Right and left hand turning tools
- Boring bar
- 1 Pkt (10) of inserts

SIZE			
12mm	$239	~~$275~~	(L450)
16mm	$259	~~$297~~	(L451)

Slot Drill & End Mill Sets

- 12 piece sets
- HSS Tinite coated
- Metric: 4-12mm
- Imperial: 3/16" - 1/2"

TYPE			
Metric	$75	~~$84.70~~	(M333)
Imperial	$75	~~$84.70~~	(M335)

EF-5S Engineers File Set

- 200mm hardened and tempered files
- Second cut: Flat, 1/2 Round, Round, Square, Triangular
- Includes carry case

$35 ~~$42.35~~ (F100)

- JAMES
Staff Member

BECOME A MACHINERYHOUSE MATE
www.machineryhouse.com.au/signup

$70 FREE DISCOUNT VOUCHERS

VIEW AND PURCHASE THESE ITEMS ONLINE AT
machineryhouse.com.au/SCSHIP17

Sydney	(02) 9890 9111	1/2 Windsor Rd, Northmead
Brisbane	(07) 3274 4222	625 Boundary Rd, Coopers Plains
Melbourne	(03) 9212 4422	1 Fowler Rd, Dandenong
Perth	(08) 9373 9999	11 Valentine St, Kewdale

Specifications & Prices are subject to change without notification. All prices include GST and valid until 31-10-17

10_SC_280917

Using Cheap Asian Electronic Modules Part 10

Two really low cost GPS receiver modules

These two GPS receiver modules combine low cost with impressive performance – making them very attractive for use in all kinds of projects. One is the V.KEL "GMouse" VK2828U7G5LF, and the other the u-blox Neo-7M module.

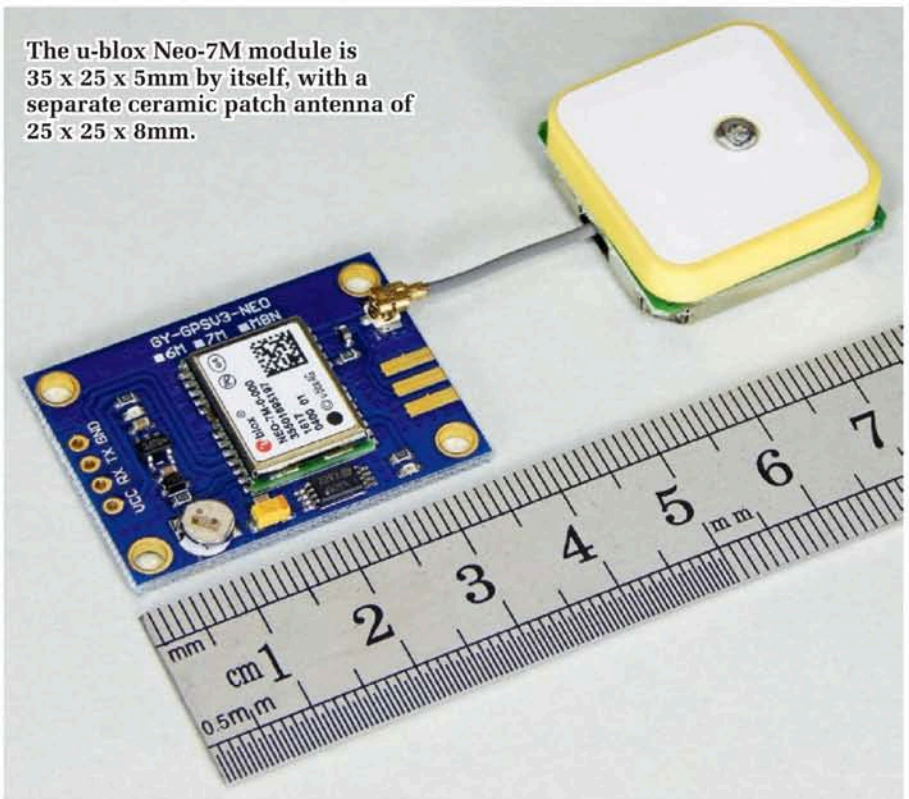
By JIM ROWE

Over the 10 years or so that GPS receiver modules have been available for use in electronic projects, they have not only improved significantly in performance but have also dropped dramatically in price.

For example, the Garmin GPS15L module we used in our GPS-derived Frequency Reference (SILICON CHIP March-May 2007) cost $130 but also needed a separately powered outside antenna/LNA which cost about half as much again.

At the time, we thought this was surprisingly cheap but by 2013 the prices for similar modules had dropped to less than $60 – despite the fact that they were more sensitive and had a built-in ceramic "patch" antenna.

But technology and market forces keep marching on and now you can buy a very compact GPS receiver module complete with ceramic patch antenna (the V.KEL Electronics VK2828U7G5LF) for around $25, which we supply on our online shop (www.siliconchip.com.au/Shop/7/3362). Or you can buy a similar unit (the u-blox Neo-7M) with separate patch antenna for as little as $16, from many different suppliers on eBay and AliExpress.



The u-blox Neo-7M module is 35 x 25 x 5mm by itself, with a separate ceramic patch antenna of 25 x 25 x 8mm.

The two modules look a little different, as you can see from the photos. For the V.KEL "GMouse", the ceramic patch antenna is mounted on the underside of the module's main PCB, while for the Neo-7M it is separate and connected to the receiver using a short length of thin coaxial cable. Both modules are built in China and they're both based on the GPS receiver engine chip (the UBX-G7020-KT), made by Swiss firm u-blox Holding AG.

Founded in 1997 as a spin-off from the Swiss Federal Institute of Technology in Zurich, u-blox had delivered one million GPS receivers by 2004 and its 10 millionth receiver by 2008. In 2011, it acquired the Californian firm Fusion Wireless and in 2012 it acquired Finland-based Fastrax.

The firm now has offices in Finland, China and Japan as well as in the USA and many European countries. You can find more about them on their website at www.u-blox.com, including a data sheet on the UBX-G7020-KT engine chip and a full data sheet on the closely related Neo-7M module.

You can also get a comprehensive data sheet for the VK2828U7G5LF module from either of these websites:

www.vkelcom.com

https://github.com/CainZ/V.KEL-GPS/blob/master/VK2828U7G5LF%20Data%20Sheet%2020150902.pdf

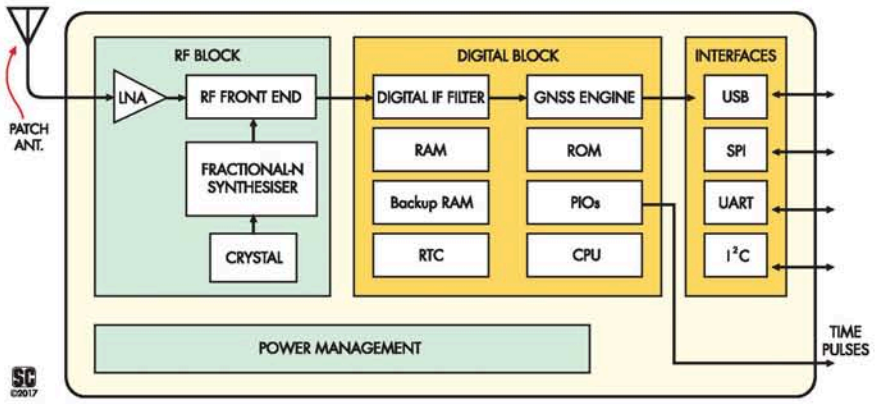


Fig.1: block diagram of the UBX-G7020-KT GPS engine chip. The whole chip is contained within a 5 x 5 x 0.6mm SMD package. Due to a multi-mode GNSS decoding engine, this chip can handle 56 channels of GPS, GLONASS or GALILEO. Note that the European GALILEO system is not yet operational.

As you can see from the block diagram in Fig.1, the UBX-G7020-KT GPS engine chip is impressive. It's a complete GPS receiving system integrated inside a 5 x 5 x 0.6mm SMD package.

There's an RF/microwave front-end receiving block with an LNA (low-noise amplifier) and a crystal-derived fractional-N frequency synthesiser for the local oscillator, with its IF output fed to a digital block with a CPU controlling a digital IF filter and a multi-mode GNSS decoding engine which can handle 56 channels of either GPS or GLONASS (Russian version of GPS) satellite signals.

Supporting the rest of the digital block are ROM, RAM and backup RAM, RTC (real-time clock) and a number of programmable I/O sections – including one which provides configurable time pulse signals (0.25Hz-10MHz) with an RMS accuracy of 30ns. Finally, there's a selection of four different output interfaces: USB, SPI, UART and I^2C.

Additionally, the cold-start sensitivity of the UBX-G7020-KT chip is claimed as -148dBm, falling to -160dBm for reacquisitions. The time to first fix for a cold start is listed as 30 seconds, dropping to one second for a hot start. In short, it's an impressive little performer.

Inside the Neo-7M

So that's a glimpse of what's inside the UBX-G7020-KT chip itself. Now let's take a look at one of the modules using it, the Neo-7M. This measures 35 x 25 x 5mm for the module itself, with the separate patch antenna measuring 25 x 25 x 8mm. You'll find the Neo-7M's full circuit in Fig.2. (We don't have the full circuit details of the VK2828U7G5LF module but it's likely quite similar.)

As you can see, there's not a lot in it apart from the UBX-G7020-KT receiver (IC1) and its matching active antenna which is a ceramic patch antenna with onboard LNA (low-noise amplifier). The antenna connects to the RF input of IC1 (pin 11) via a 20mm length of very small diameter coax and a pair of ultra-miniature U.FL coax connectors. DC power to operate the LNA is provided via inductor L1 and its series 22Ω resistor, connected to pin 9 of IC1.

Now the UBX-G7020 is designed to operate from a 3.3V supply, so the module includes a low-dropout regulator (REG1) so that it can be connected directly to a 5V DC supply. Note that there's also a pill-sized rechargeable backup battery connected to pin 22 of IC1 which is charged via diode D1 and the series 1kΩ resistor when power is applied to the module.

But what's the purpose of IC2, a 32Kb (4KB) EEPROM? It is provided in order to save the UBX-G7020's configuration data, since many aspects of its configuration can be changed – such as the I/O port to be used, the frequency of its time-pulse output and so on.

The Neo-7M module leaves the factory with a default configuration where the UART and I^2C I/O ports are activated, with the UART I/O set for a bit rate of 9600 baud and "8N1" no-handshaking. The time-pulse

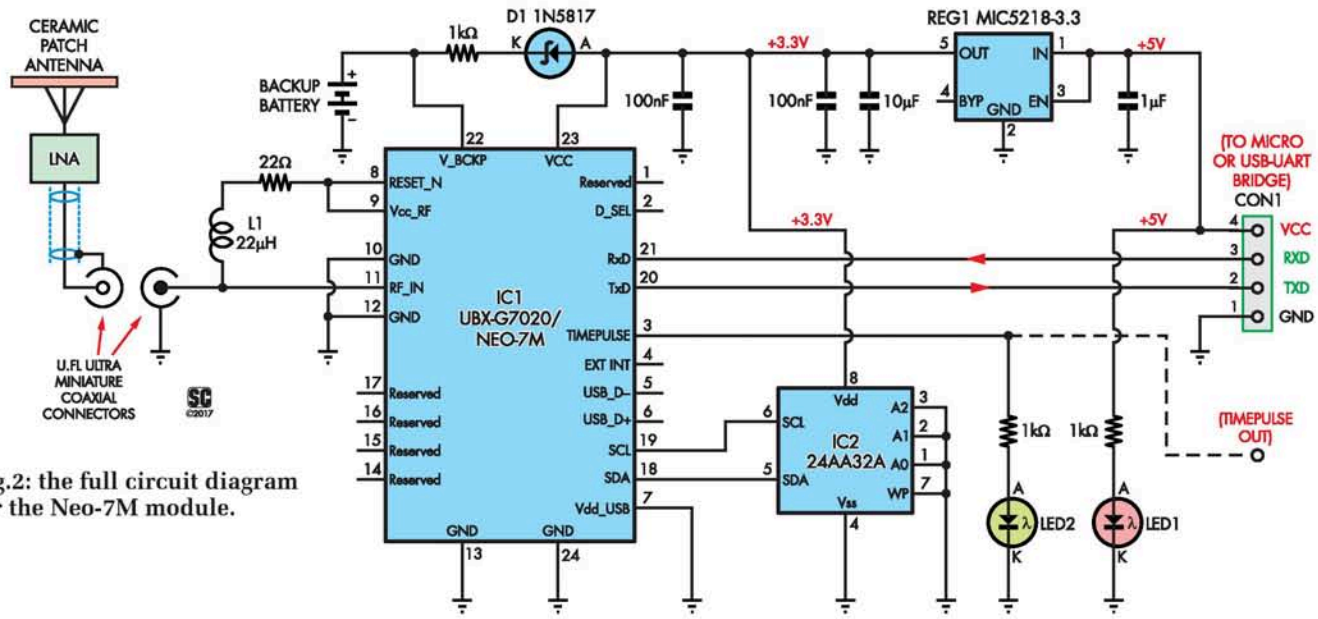
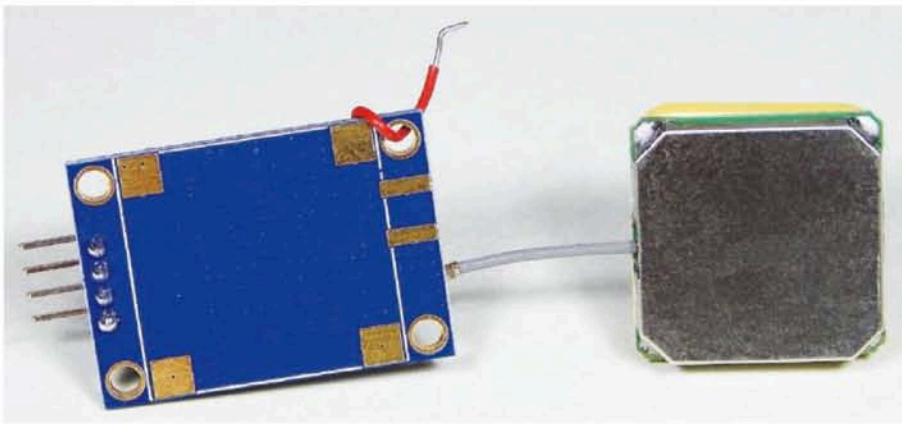


Fig.2: the full circuit diagram for the Neo-7M module.



Underside of the Neo-7M and separate ceramic patch antenna. The outer two gold rectangular pads on the Neo-7M can be used to provide an earth connection, which can be useful if you need an outdoor antenna.

frequency is also set for 1Hz. However, it's also programmed to save its configuration data in external memory, via the I^2C port, so that it can retrieve this information each time it's powered up.

The module designers have provided IC2 to save this configuration data, so if you want to change the Neo-7M's configuration, it's possible to do this by reprogramming IC2. Most users probably won't want to do this, though, because the default configuration is likely to be suitable for most common applications.

That's about it, apart from the two LEDs. Red LED1 is provided as a power indication, lighting up whenever +5V power is provided to the module via pin 4 of CON1. And green LED2 is connected via a second 1kΩ resistor to pin 3 of IC1, which is the time pulse output.

So LED2 flashes once per second (with the default configuration), once the UBX-G7020 has achieved a fix from the GPS satellites. This usually happens less than 30 seconds after applying power, assuming the antenna has a reasonable view of the sky.

Unfortunately, the designers of this module have not provided a specific output on the PCB for taking off the 1pps/time pulse signal for external use. But it's not all that hard to do this yourself, with a small amount of surgery.

All you need do is to identify the PCB track connecting pin 3 of IC1 to the top end of the 1kΩ resistor next to LED2 and then scrape some of the protective lacquer from the top of the track as close as possible to the resistor's mounting pad. Then you need to tin it quickly with your fine-tipped soldering iron, so that you can solder the bared end of a short length of hookup wire to the top of the tinned track.

This isn't quite as simple as it might sound. For a start, the PCB track concerned is only about 0.5mm wide. So you have to do the scraping very carefully and the tinning and soldering as quickly as possible – otherwise the track may detach from the PCB laminate and break off, removing the connection to pin 3 of IC1 altogether.

Can't you simply solder the wire to the pad at the outer end of the 1kΩ resistor, to avoid risking damage to the thinner track? Yes, you can but when I tried this myself the solder joint between the resistor and the pad underneath lifted slightly, breaking the connection to the track for both the resistor and the added wire.

So LED2 no longer flashed and there were still no 1pps pulses available via the added wire. Then when I tried resoldering things, the original 1kΩ SMD resistor overheated and came off altogether.

So I decided to try re-soldering the 1pps takeoff wire to both the resistor pad and the track to pin 3 of IC1, and then fitting a new 1kΩ (0805) resistor in place of the old one – mounted at an angle, so that its outer end could be soldered to the top of the takeoff wire.

This looks a bit messy, as you can see from the photo below but it does work. You should also be able to see from the photo that I looped the takeoff wire through the PCB mounting hole nearby, to avoid stress on the solder joint when the outer end of the wire is moved around.

I also soldered the end of another short length of hookup wire to the nearest of the three long gold-flashed pads at that end of the PCB, to make another ground connection. This wire was also looped through the PCB mounting hole.

Incidentally, those three long gold-flashed pads at the end of the module's PCB seem to have been provided to allow fitting a PCB edge-mounting SMA socket, for connection of an alternative external active GPS antenna. The two outside pads are connected to PCB ground, while the inner pad is connected to the RF input between the U.FL connector and pin 11 of IC1.

There are also two gold-flashed pads on the underside of the PCB, directly under the two outer pads and connected to ground as well. It's an option that could be handy in applications where you must have an outside antenna.

Inside the VK2828U7G5LF

Detailed information regarding the internals of the V.KEL VK2828U7G5LF module is limited. The manufacturer's data doesn't say much at all, apart from confirming that it uses the u-blox UBX-G7020-KT engine chip, giving the pin designations for the module's 6-pin power/IO connector and also giving the overall dimensions of the module as 28 x 28 x 8.6mm.

Some circuit work is needed to take a 1pps/time pulse signal for external use on the Neo-7M. This is done by attaching hookup wire on the PCB track connecting pin 3 of IC1 and the 1kΩ resistor next to LED2. The second hookup wire you can see is attached to one of the gold pads to provide another ground connection.

However, a quick visual inspection of the module when powered up and working revealed another detail: this module provides two PPS indicator LEDs – one on the top of the module's PCB like the red power LED, and the other on the other side of the PCB just at the end of the patch antenna. So as the module would normally be placed antenna side uppermost for best GPS reception, this means that this second PPS LED will always be visible – a nice feature.

Fig.3 shows all of the available information regarding the internals of the VK2828U7G5LF module. We have labelled the two PPS LEDs LED2 and LED3 since there are no markings on the PCB. One final point which should be noted is that this module does provide a specific output pin for the PPS pulses, so no surgery is required to make use of these pulses.

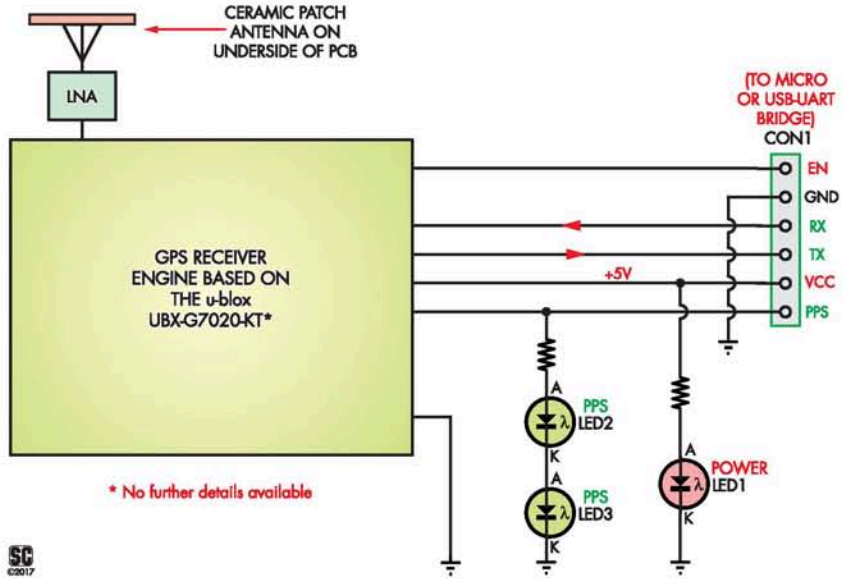


Fig.3: what we can infer about the internals of the VK2828U7G5LF module. Note that this module, unlike the Neo-7M, provides a specific output pin for 1pps/ time pulse signals.

Putting them to use

It's actually quite easy to make use of either of these GPS receiver modules. As a bare minimum, all you need to do is hook them up to a source of 5V DC and then connect the TX/TXD output to the RXD input of your Arduino, Micromite or other micro, to feed it with the module's NMEA (National Marine Electronics Association) data stream.

Note that with the VK2828U7G5LF module both the E/E_N and V/V_{CC} wires should be connected to +3.3V or +5V, while with the Neo-7M module only the V_{CC} pin (pin 4) is connected to +5V.

To show how easy it is to connect one of these modules to a Micromite, I can refer you to Geoff Graham's article in the April 2016 issue of SILICON CHIP describing his Touch-Screen Boat Computer with GPS. There's also quite a bit of information on the web describing how to use this type of module with an Arduino.

It's also surprisingly easy to connect up the module to a PC. All you need is one of the little UART/USB bridge modules, like the one we discussed in the third article in this series (see the January 2017 issue of SILICON CHIP).

As you can see from the diagrams of Figs.4 & 5, you just need to make the correct interconnections between the two modules (note the crossover between the two serial data lines) after which the USB socket on the bridge module can be connected to a USB port on your PC via a standard USB cable.

The nice thing about this approach is that power for both modules comes from the PC via the USB cable, so no separate power supply is needed. In passing, the current drawn from the USB supply by either GPS receiver module plus the UART-USB bridge module combination is only about 60mA.

Remember that when you first plug the cable from the UART/USB bridge into a USB port on your PC, Windows should automatically install the correct VCP (virtual COM port) driver for it. So before proceeding further, it's a good idea to fire up Control Panel and check that the driver has been installed – also noting the COM port number it has been given (like COM5, COM8 etc).

You should be able to configure the port settings – in this case for communication at 9600 baud, with no handshaking and 8-N-1 (8 data bits, no parity and 1 stop bit) data formatting.

Once the simple setup of Fig.4 or Fig.5 is hooked up to your PC and the LEDs on the modules indicate that it's running, you can easily monitor the NMEA data stream coming from the GPS receiver using a serial terminal emulator program like Tera Term.

This is a very stable serial terminal emulator written originally by Japanese software designer T. Teranishi, which has been maintained as free open-source software since 2007 by the Tera Term Project.

You can download it from either of

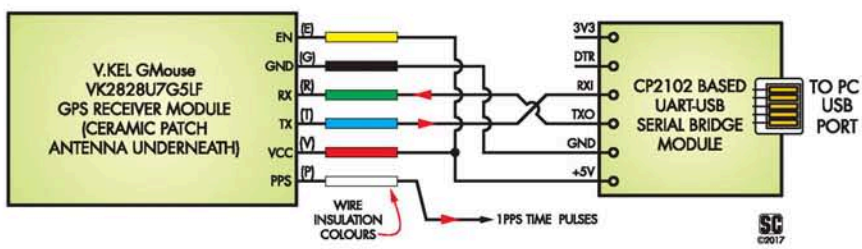
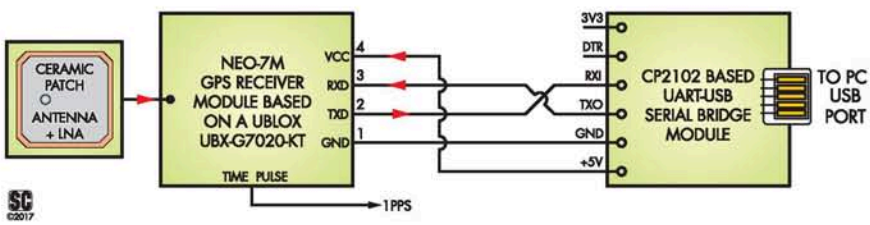


Fig.4 (top): required connections to connect the VK2828U7G5LF to a computer.
Fig.5 (bottom): required connections for the Neo-7M to connect to a computer.



GPS in a Nutshell

GPS or the Global Positioning System was the first global navigation satellite system (GNSS) to become fully operational, in 1995 (the 24th orbiting GPS satellite had been launched in 1994).

GPS was developed by the US Department of Defense (DoD) and was initially intended for use only by the US military, with the signals intentionally degraded for non-military users via a system known as "Selective Availability". However, Selective Availability was turned off in May 2000, following a policy directive that had been signed by President Bill Clinton in 1996.

Since then, the uses of GPS by civilians have grown almost exponentially, not just in the USA but all around the planet. GPS receivers are now incorporated into mobile phones, laptops and touch-pad PCs, navigation receivers for cars, trucks and buses, tracking systems for trains and light-rail systems and of course navigation receivers for aircraft, ships and boats.

By February 2016, the number of satellites orbiting in the GPS constellation had risen to 32, with 31 of them in use and one a spare in case of a failure. Strictly speaking, only 24 orbiting satellites are needed for navigation anywhere on the globe because this ensures that four satellites are visible at all times. However, the additional satellites provide worthwhile redundancy and improves receiver accuracy.

But how does GPS actually work? Well, all of the GPS satellites orbit the Earth at an altitude of approximately 20,200km, in orbital planes that are tilted at approximately 55° to the equator. They're orbiting at a speed such they make one full revolution in half a sidereal day (11 hours and 58 minutes). The orbits are arranged so that at least six satellites are always within line-of-sight from virtually anywhere on the planet's surface.

Inside each satellite there are two caesium-beam atomic clocks, and the satellites all make frequent radio contact with each other as well as with dedicated ground monitoring stations. As a result, each satellite always knows two crucial parameters with great accuracy: the current GPS/UTC time and its own current location in terms of latitude, longitude and altitude.

Each satellite also contains a CDMA spread-spectrum microwave transmitter, which continually broadcasts its current time and location data on a number of frequencies – mainly 1.57542GHz (the "L1" signal) and 1.2276GHz (the "L2" signal). Although all of the satellites use the same frequencies, the signals from each satellite are encoded with a different high-rate pseudorandom sequence, so receivers can always identify from which satellite any signal is originating.

This allows a GPS receiver to work out its own current location by decoding and comparing each of the signals currently being received from at least four satellites. It does this by measuring the time taken for the signals to come from each satellite, at their specified locations. This allows it to calculate its distance from each satellite, and then to find its own location by finding the intersection of these multiple path distances – a technique called triangulation.

But a GPS receiver doesn't just provide this accurate location information. Most GPS receivers actually provide a continuous stream of many items of data, in a format known as the NMEA 0183 data stream (where NMEA stands for the US National Marine Electronics Association). This emerges from a GPS receiver as alphanumeric serial CSV (comma separated variable) data, usually at a rate of 4800 or 9600 baud (bits/second). It's in the form of a number of one-line message "sentences", each one identified by a unique header word. All of these header words begin with the characters "$GP", but are then followed by a three-letter combination identifying the type of sentence.

Perhaps the most useful message sentence for many applications is the one carrying the $GPRMC header, also known as the Recommended Minimum sentence. This provides the current UTC time, the receiver's latitude and longitude, its speed in knots (not very useful when operating in a fixed location) and the date.

As well as providing this handy data stream (updated every second), most GPS receivers also provide a 1pps time pulse each second, with its leading edge accurately locked to GPS/UTC time. This makes them especially useful for synchronising clocks and frequency references.

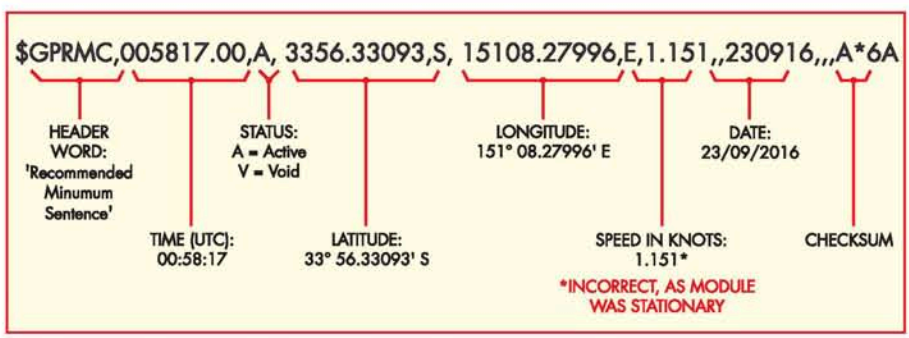


Fig.6: shows the way $GPRMC header data is arranged.

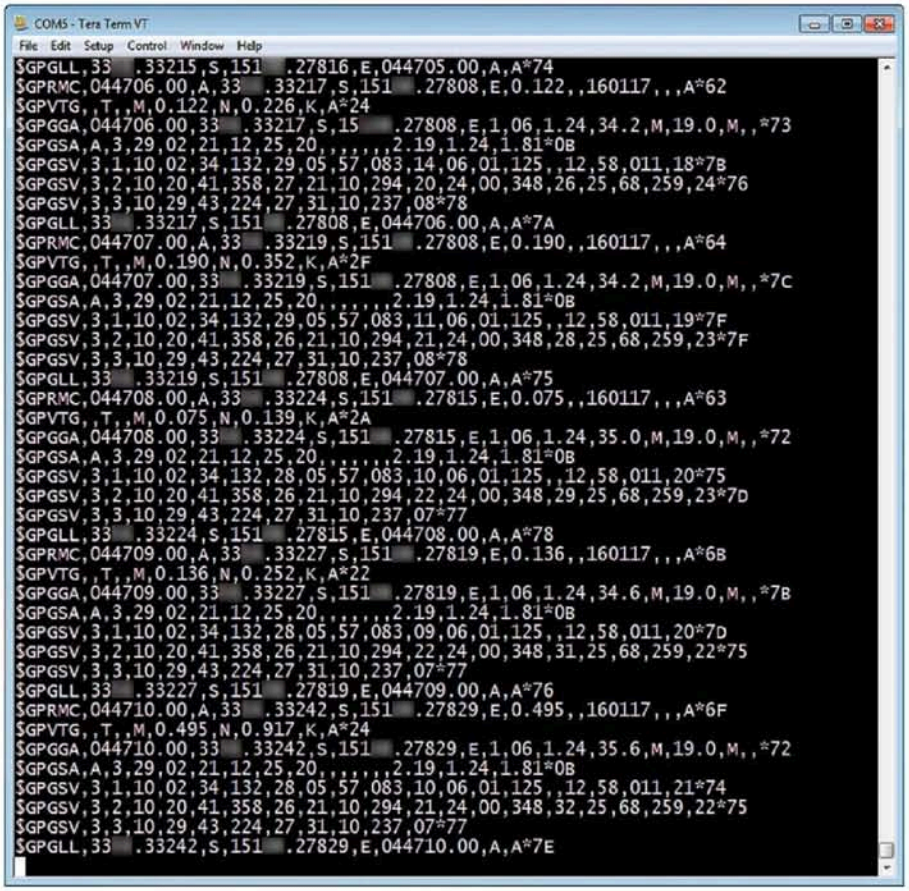
these websites:

https://osdn.net/projects/ttssh2/releases/

http://download.cnet.com/Tera-Term/3000-20432_4-75766675.html

At the time of writing, the current version is 4.92.

When you install Tera Term and first start it up, you'll need to set it up before proceeding. Do this by clicking on the Setup menu, and then on "Terminal". Then in the dialog that



Data stream from the GPS receiver being viewed in Tera Term.

appears, set the New-Line Receive mode to AUTO, check that the terminal ID shows as "VT100" and that the Local echo is **not** selected.

Then exit from the Setup Terminal dialog and click on the Setup menu again, but this time drop down to click on "Serial Port". Then in the new dialog that appears, set the Port to the VCP number that you saw in Control Panel and make sure that the data rate is set to 9600 and the format to 8-N-1.

Finally, click on the Setup menu one more time and drop down to click on "Save setup". This will let you save the new setup so that in future when you start up Tera Term, it will be able to begin accepting the data stream from your GPS receiver without any further ado.

In fact, as soon as you finish saving the setup, Tera Term should immediately swing into action, receiving the GPS data stream and displaying it in its main window as shown in the adjacent screen grab. Notice that there are quite a few data sentences sent by the GPS receiver each second, as well as the one with the "$GPRMC" header.

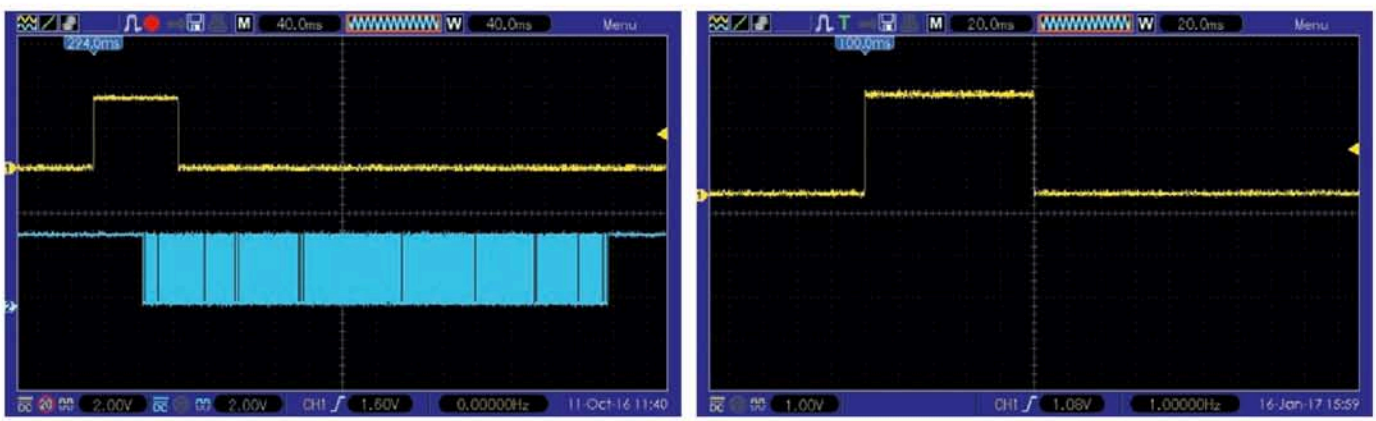
Fig.6 shows the way the time, location and date information is arranged in the $GPRMC sentences. This should be enough for many people, but if you need to analyse any of the other sentences you can get a lot of useful information by using this link:

www.gpsinformation.org/dale/nmea.htm

The UBX-G7020-KT GPS receiver chip used in both modules can be programmed to change various parameters in its NMEA 0183 output stream – for example to select or deselect any of the data sentences, change the data rate from the default 9600 baud and so on. It can also be instructed to change the PPS rate from the default 1pps up to 10pps. All of these changes are made by sending a hexadecimal data stream to the chip via the RX/RXD serial input. This is explained in the VK2828U7G5LF data sheet.

I hope the foregoing gives you enough insight into either of the GPS receiver modules based on the u-blox UBX-G7020-KT chip, so that you'll be confident in getting one and trying it out.

In closing perhaps I should mention that you don't even have to hook up the receiver modules to a UART-USB bridge module as per Figs.4 and 5 in order to use it purely for extracting 1pps pulses from the GPS signals to drive a digital clock or a GPS-disciplined frequency reference. All you'll need to do is connect the module's V_{CC} (or V_{CC} and E_N) and GND lines to a source of 5V DC, and away it will go. SC



The left plot shows the 1pps pulse and NMEA (National Marine Electronics Association) data from the Neo-7M while the right plot shows just the 1pps pulse data from the VK2828U7G5LF.

KELVIN, the clever cricket

Kelvin, the electronic cricket, is a bit of a smart alec. Just like a real cricket, he only starts chirping in the dark. And also like a real cricket, the warmer it is, the more rapidly he chirps. So you can actually tell the temperature, based on the sounds he makes!

By All-rounder John Clarke

As well as being quite useful, Kelvin is easy to build, consisting of around 20 through-hole components. It runs from a Lithium button cell and because it's power efficient, you won't have to change the cell too often. It's a great project for beginners but experienced constructors will enjoy this one too.

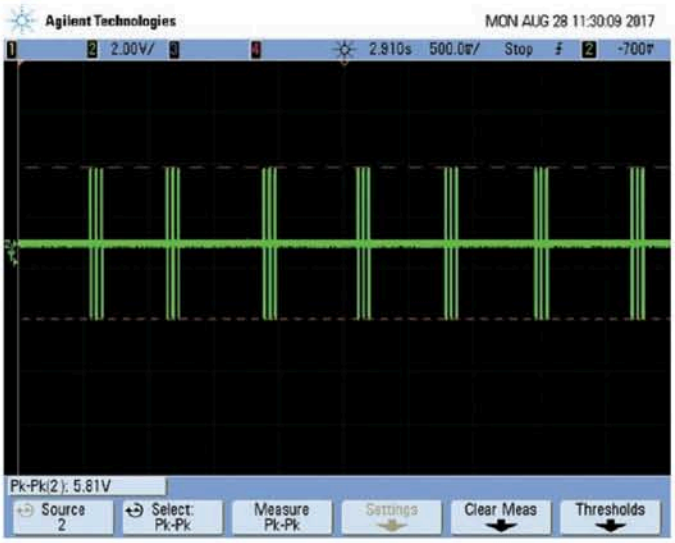
Talking about the temperature or cricket is always a good conversation starter *[Editor's note: this may be a different kind of cricket. . .]*.

With Kelvin, the clever cricket, you can talk about both at once. Sure, you could check the temperature on your smartphone but that's so. . . boring. Using an electronic cricket is a much more entertaining method and a bit of a conversation starter, too.

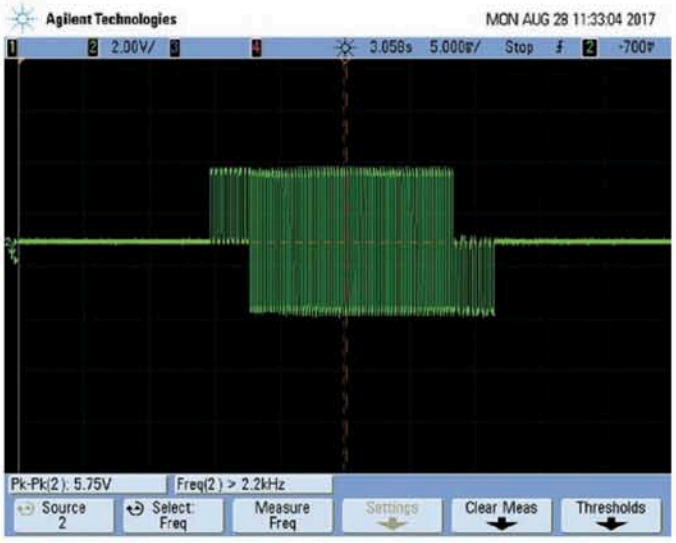
Mind you, Kelvin is just like a real cricket in that he won't make a single chirp in daylight. It needs to be dark before he finds his voice.

Then you simply need to count the number of chirps Kelvin makes to obtain the temperature reading.

We have included various chirping options to speed up



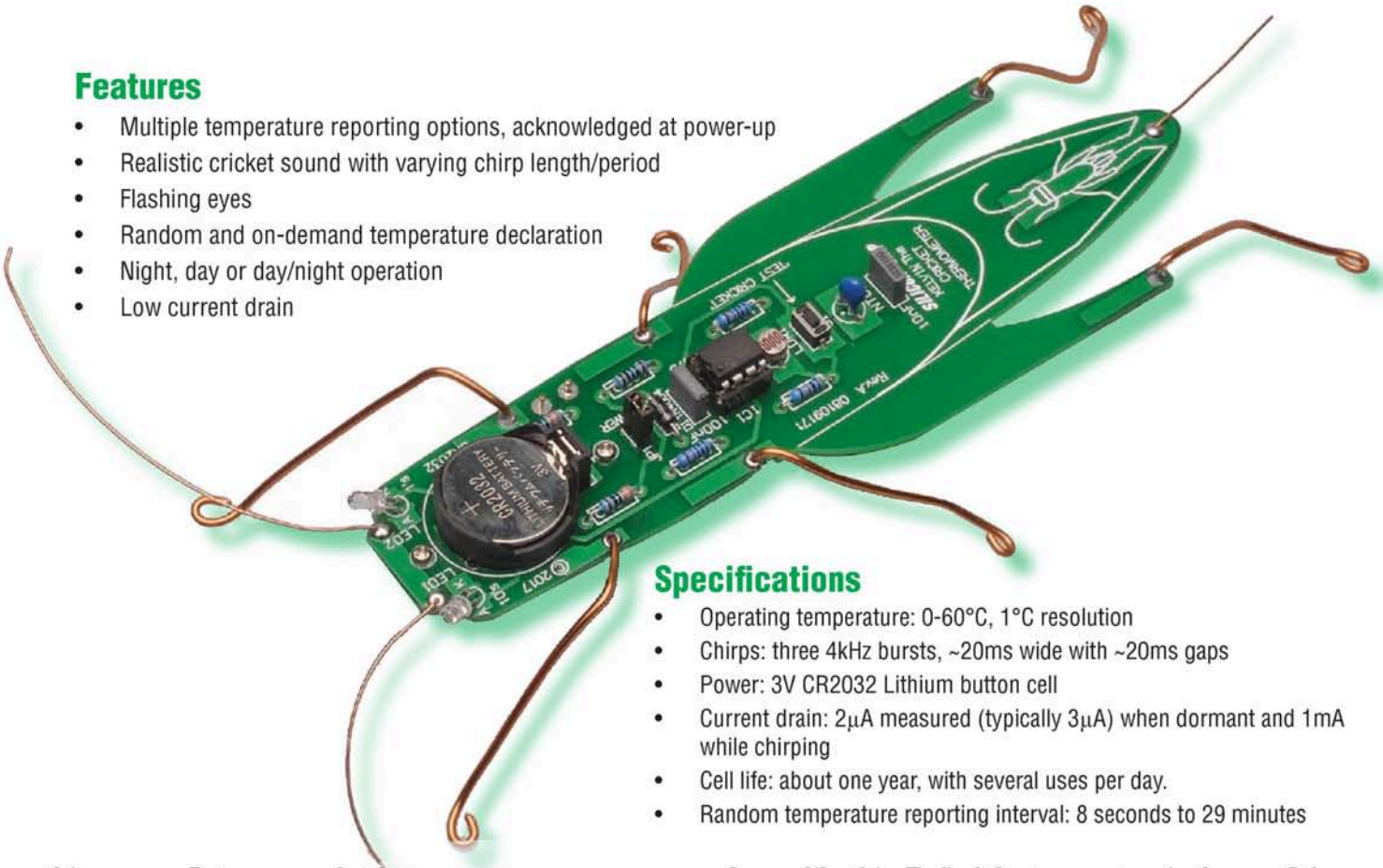
Scope1: this shows the typical cadence of chirps emitted by Kelvin, the clever cricket. Each chirp consists of three 20 millisecond bursts at 4kHz from its piezoelectric transducer. Note that the gap between each chirp is uneven, similar to that from a real cricket.



Scope2: a burst of 4kHz, measured between pins 2 & 3 of the PIC12F675 microcontroller. Since the piezoelectric transducer is driven in bridge mode from the microcontroller, the waveform amplitude is almost double that of the battery voltage (3V).

Features

- Multiple temperature reporting options, acknowledged at power-up
- Realistic cricket sound with varying chirp length/period
- Flashing eyes
- Random and on-demand temperature declaration
- Night, day or day/night operation
- Low current drain



Specifications

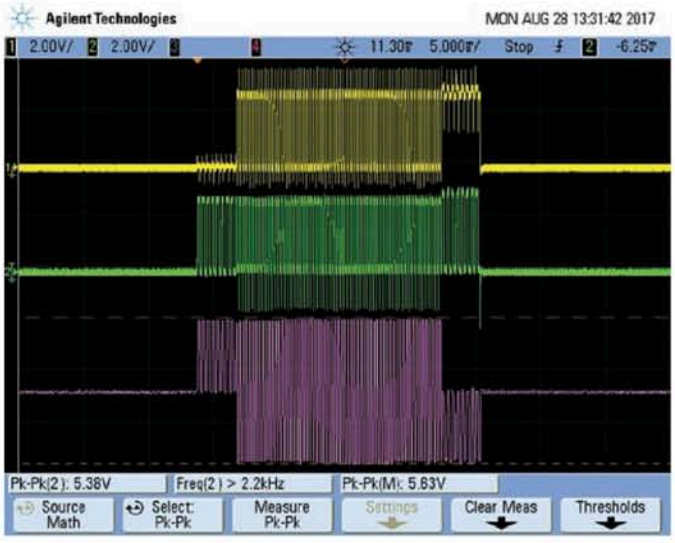
- Operating temperature: 0-60°C, 1°C resolution
- Chirps: three 4kHz bursts, ~20ms wide with ~20ms gaps
- Power: 3V CR2032 Lithium button cell
- Current drain: 2μA measured (typically 3μA) when dormant and 1mA while chirping
- Cell life: about one year, with several uses per day.
- Random temperature reporting interval: 8 seconds to 29 minutes

this process. But more on that later.

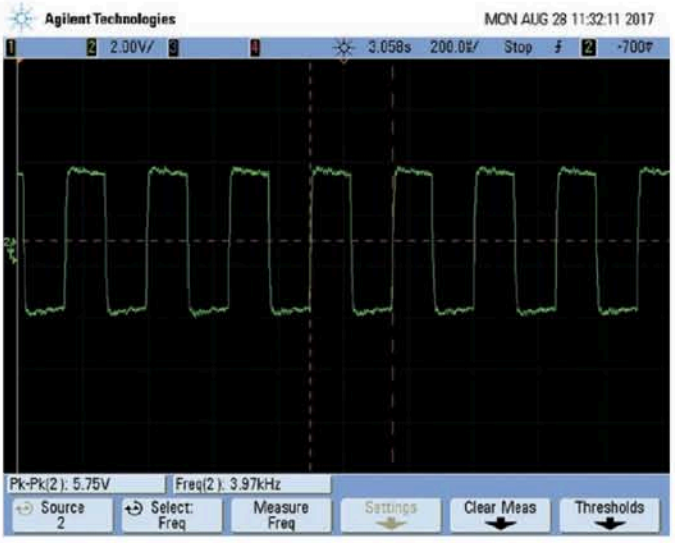
Real crickets do tell the temperature

It has been known for more than a century that crickets chirp at a rate that is related to temperature. Back in 1881, Margarette W. Brooks established a relationship between air temperature and a cricket's chirp rate. Her work was followed by that of Amos Dolbear in 1897 and as a result, the formula for estimating the chirping rate is known as Dolbear's Law.

It goes like this: To find the temperature in degrees Celsius, count the number of cricket chirps over a one minute period. Then subtract 40, divide the result by seven and then add 10. If the mental arithmetic this formula requires stumps you (sorry!) it is unlikely that a cricket ever intended its chirping rate to be used in this manner. Evidently, crickets just use a different and non-linear temperature scale compared to us humans. The cricket chirp rate represents their own °C scale, where the C stands for Cricket. (Crickets are cleverer than humans – they knew



Scope3: the output signals at pins 2 & 3 (yellow & green traces) while the purple trace shows the summed amplitude which drives the piezoelectric transducer. Note that there are lots of overshoots in the two output signals which do not appear in the summed output.



Scope4: the 4kHz square wave signal which is emitted in bursts from pins 2 and 3 of the PIC12F675 microcontroller and fed to the piezoelectric transducer. Considering that this a flea-power circuit is really quite loud – just like a real cricket!

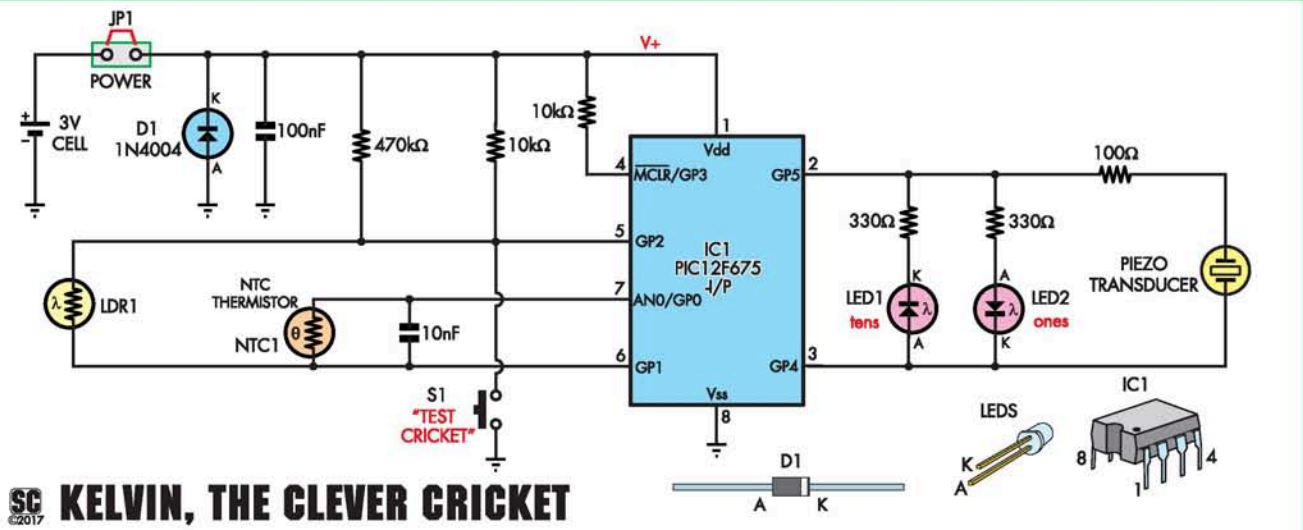


Fig.1: complete circuit for Kelvin the cricket. This is based around microcontroller IC1 which monitors the resistance of LDR1 to sense the ambient light level and NTC1 to sense the temperature. The GP4 and GP5 outputs from IC1 drive the piezo transducer and also the two LEDs for the cricket's eyes.

all along that we couldn't make our minds up whether our "C" stood for Centigrade or Celsius).

Since Kelvin is a clever electronic cricket, you don't have to do this mental arithmetic. It produces the temperature directly in °C – Celsius, that is. Not only does that make it easier but it also reduces the amount of chirping required. Dolbear's Law reveals that temperature in degrees Cricket is a gruelling scale that requires a lot of chirping.

For example, at 25°C, to chirp out the temperature in degrees Cricket, the cricket would need to chirp some 145 times each minute.

Another thing to note from Dolbear's Law is that a cricket does not report temperatures below about 4°C. That's when the number of chirps required to report this temperature is equal to zero. However, if you don't hear any crickets chirping, that may not mean that the temperature is too cold. Instead, there may be an absence of crickets. You can solve that by building Kelvin.

Cricket sounds

Crickets produce chirping sounds by rubbing a coarse section of one wing against a scraper located on the other wing. This process is called stridulation and it's a bit like flicking a fingernail along the teeth of a comb.

For a cricket, the reporting of the temperature is a secondary consideration. Crickets are more concerned about making these sounds to establish their territory or to attract a mate. With regard to the latter, it means that the male cricket is attempting to "bowl a maiden over" *[Editor's note: we again apologise for this terrible pun].*

That stands to reason though. Since crickets are cold-blooded, the stridulation rate would vary with temperature. A cricket's wing muscles would tend to be rather slow-acting at low temperatures compared to when they warm up as temperature rises.

Typically, the sound a cricket produces comprises three closely spaced chirps, followed by a longer gap, then another three and so on (ie, they have a particular cadence).

A typical cricket chirp comprises three bursts of a 4kHz tone with each burst lasting for around 50ms. The spacing between each chirp is also around 50ms. The separation between each triplet is around 250ms. These periods are not precise and do vary a little. The tone of the chirp, however, does not appear to vary by any noticeable degree.

Kelvin's chirps follow the same pattern, with three 4kHz bursts, each separated by a longer gap. However, we found that driving a piezo transducer with three 50ms burst and 50ms gaps for each chirp tended to sound more like an umpire's whistle than a cricket.

In order to sound more realistic, Kelvin's chirps are 20ms bursts of 4kHz with 20ms gaps between them. Scope1 is a screen grab which shows the chirp cadence on an oscilloscope.

But a real cricket does not chirp at precise intervals – they're quite irregular. To simulate this, Kelvin's chirping periods vary randomly over a limited range. In other words, they aren't always exactly 20ms long or spaced apart by exactly 20ms.

The variations in the periods lend Kelvin a more natural cadence and prevent the simulated cricket chirp from sounding artificial.

Delivery

Kelvin can produce one chirp per degree Celsius. In this mode, the chirp rate will vary with temperature, to keep the chirping period to a reasonable length. This is similar to the behaviour of a real cricket.

But that still means you could need to count many chirps in hot weather and it's quite easy to lose track. So Kelvin can optionally produce chirp triplets in sets of five, six or ten.

The gaps between the chirp triplets are deliberately made short so they are easily recognised. The remainder of the temperature value is delivered as single chirp bursts with a wider gap.

So if you have set the temperature to be reported in sets of five (see "modes" in Table 1) and the temperature is 27°C, there will be five sets of five delivered (for 25), followed by two separate chirps to add up to 27.

Why did we include an option for six chirps? Well, obviously that's because, in cricket, there are six balls to an

over. So if you're a cricket fan and you are used to counting balls and overs, this should be natural for you. *[Editor's note: John appears to be deliberately conflating crickets with cricket. We suspect he may be a cricket tragic – in more ways than one!]*

Physical appearance

Kelvin has a cricket-shaped PCB (funny, that). Crickets can be black, brown or green; Kelvin happens to be green. Most components are mounted on Kelvin's back, with its eyes being 3mm red LEDs. The piezo transducer that produces the cricket sound is slung under Kelvin's abdomen.

Kelvin's six legs are fashioned from thick 1.25mm copper wire. As well as the LBW (legs being wire), the two antennae and ovipositor (tail) are also made from wire; a thinner gauge, at 0.5mm diameter. We make no comment about Kelvin being an apparently male cricket (do you know any females named Kelvin?) and equipped with an ovipositor.

Circuit description

The complete circuit is shown in Fig.1. It's based around microcontroller IC1, a PIC12F675, which is powered by a 3V lithium cell. Power is applied when jumper JP1 is inserted. It does not draw much current, typically only about 3µA while Kelvin is dormant. This rises to around

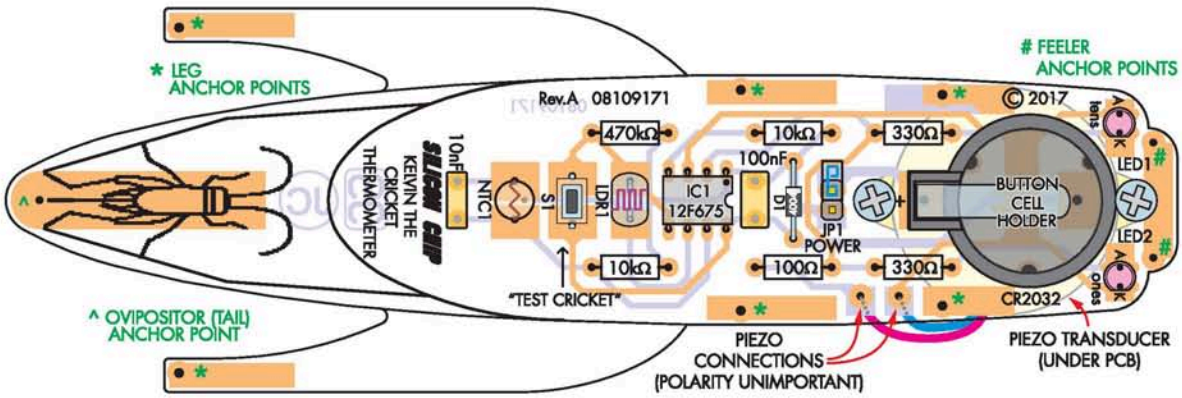
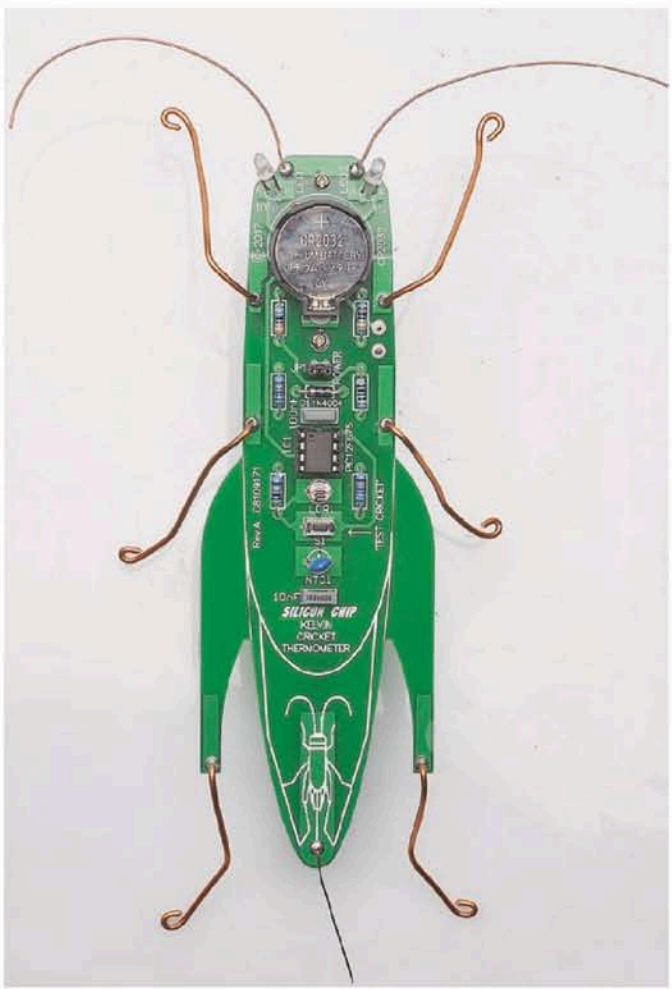
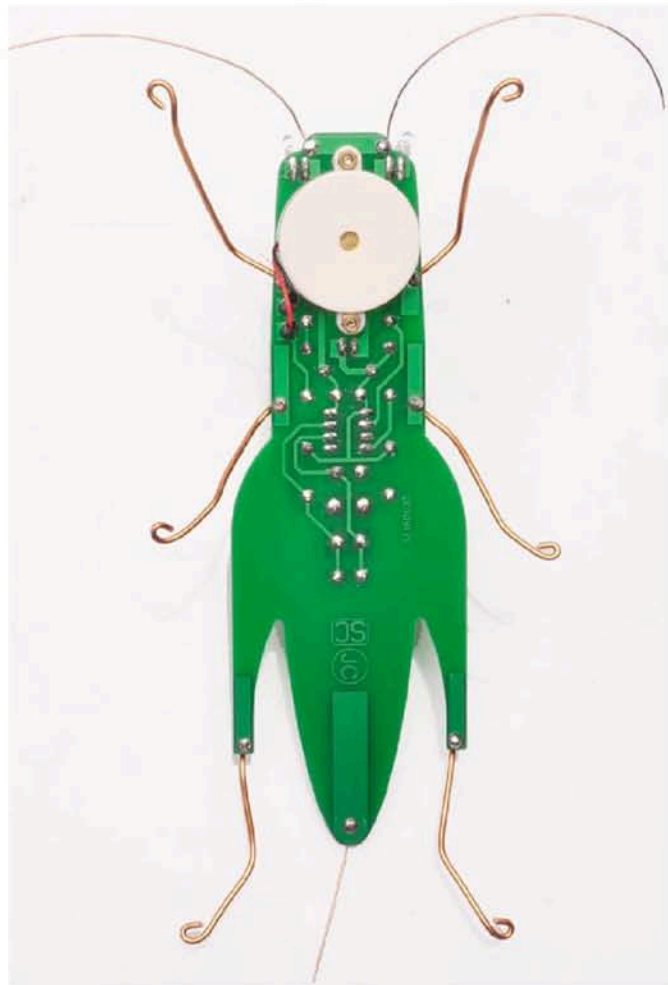


Fig.2: most of the parts are fitted on the top side of the PCB, with just the piezo transducer being mounted underneath, held in place by M2 machine screws. Take care that the button cell holder, IC1, D1 and the LEDs are oriented correctly (ie, as shown here).





Parts list – Kelvin the Cricket

1 double-sided shaped PCB, coded 08109171, overall 155 x 51mm
1 20mm button cell holder [Jaycar PH-9238, Altronics S 5056]
1 CR2032 lithium cell (3V)
1 30mm diameter piezo transducer (PIEZO1) [Jaycar AB-3440, Altronics S 6140]
1 LDR, 10kΩ light resistance (LDR1) [Jaycar RD-3480, Altronics Z 1621]
1 NTC thermistor, 10kΩ at 25°C (NTC1) [Jaycar RN-3440]
1 momentary 2-pin pushbutton switch (S1) [Jaycar SP-0611, Altronics S1127]
1 8-pin DIL IC socket (IC1)
2 TO-220 insulating bushes (for mounting PIEZO1)
2 M2 x 8mm screws and nuts (for mounting PIEZO1)
1 2-way, 2.54mm pin header with jumper shunt (JP1)
1 400mm length of 1.25mm diameter enamelled copper wire
1 200mm length of 0.5mm diameter enamelled copper wire
2 PC stakes
1 25mm length of 1.5mm heatshrink tubing

Semiconductors

1 PIC12F675-I/P microcontroller programmed with 0810917A.HEX (IC1)
1 1N4004 1A diode (D1)
2 3mm high brightness, clear lens red LEDs (LED1,LED2)

Capacitors

1 100nF 63V or 100V MKT polyester *(code 104 or 100n)*
1 10nF 63V or 100V MKT polyester *(code 103 or 10n)*

Resistors (all 0.25W, 1% – 4-band codes shown)

1 470kΩ	(Code yellow purple yellow brown)
2 10kΩ	(Code brown black orange brown)
2 330Ω	(Code orange orange brown brown)
1 100Ω	(Code brown black brown brown)

1mA while chirping.

Diode D1 is included as a safety measure to prevent damage to IC1 should the cell be connected incorrectly somehow. This could happen if Kelvin is powered from an external 3V source which is connected back to front. In this case, D1 will prevent more than -1V being applied to IC1.

However, with a correctly installed cell holder, of the same type we used, there is no way that the button cell can be inserted to produce the wrong polarity supply voltage.

IC1's power supply is bypassed with a 100nF capacitor and IC1 runs using its internal 4MHz oscillator. When Kelvin is dormant, this oscillator is shut down (ie, sleep mode) to save power. A "watchdog" timer remains running to wake IC1 periodically (at approximately 2.3 second intervals).

During the waking period, IC1 checks the ambient light level from the light dependent resistor, LDR1. Normally, the GP1 output of IC1 is set high (3V) so there is no current flow through the 470kΩ resistor and the LDR. Again, this is done to minimise current drain.

When IC1 is awake, it sets the GP1 output low (0V) and the LDR forms a voltage divider in conjunction with the 470kΩ resistor across the 3V supply. The voltage across LDR1 is monitored at the GP2 digital input.

In darkness, the LDR resistance is high (above 1MΩ) and so the voltage at the GP2 input is more than 2V, due to the voltage divider action of the LDR and the 470kΩ resistor. This voltage is detected as a high level by IC1. With more light, the LDR resistance drops to around 10kΩ so the voltage divider produces a low level at the GP2 input.

When the GP2 input is low (the light level is high), chirping may be disabled, depending on the mode (explained later).

Kelvin can also be woken up by pressing S1. When closed, GP2 is pulled low (to 0V) and IC1 wakes up and reads the temperature using a Negative Temperature Coefficient (NTC) thermistor, NTC1. Like the LDR, this thermistor is only powered when the GP1 output is low and that's only briefly, to reduce power consumption.

The NTC Thermistor has a resistance of 10kΩ at 25°C. This forms a voltage divider with the 10kΩ resistor connected to the 3V supply. Since the two resistances are equal at 25°C, the voltage at the AN0 input will be at half-supply, ie, around 1.5V. This is converted to a digital value by IC1's internal analog-to-digital (A/D) converter. The 10nF capacitor between pins 6 and 7 stabilises this voltage.

As temperature falls, the thermistor resistance rises and voltage at the AN0 input also rises. Conversely, with temperatures above 25°C, thermistor resistance falls and voltage at the AN0 input falls. The change in resistance with temperature is non-linear and we use a software lookup table within IC1 to convert the measurement from AN0 to a temperature value.

The table contains values from 60°C down to 0°C. Kelvin hibernates at temperatures below 1°C anyway.

While the voltage at AN0 will vary depending on the supply (cell) voltage, so does the A/D converter's reference voltage, which is derived from pin 1 (V_{DD}) of IC1. So these changes cancel out and the temperature readings are stable even if the supply voltage varies.

Accuracy of temperature measurement

Although the general purpose NTC thermistor specified for this project will be accurate to within a few degrees, you may prefer greater accuracy. In this case, you could use a thermistor such as the AVX NJ28NA0103FCC which also has a 10kΩ nominal resistance and a ±1% tolerance at 25°C. It has a beta value of 4100 ±1%. The beta value defines the shape of the resistance/temperature curve.

The NJ28NA0103FCC is available from RS at siliconchip.com.au/link/aaf7

Driving the piezo transducer

IC1's GP4 and GP5 output pins drive the LEDs which form Kelvin's eyes, as well as the piezo transducer which produces the chirps. The piezo is driven in bridge mode, connected across these two outputs, which increases the AC voltage to produce a louder sound.

When GP4 is high, the GP5 output is low and when the GP4 output is taken low, GP5 is taken high. In one condition there is +3V across the piezo transducer and in the other, -3V, producing a 6V peak-to-peak square wave.

This is shown in Scope3 and Scope4. The yellow trace in Scope3 shows the waveform at GP4 and the green trace is the output of GP5. The pink trace shows the difference between them and as you can see, it has a higher amplitude.

A 100Ω resistor limits the peak current into the transducer's capacitive load immediately after the outputs switch.

LED1 and LED2 are independently driven via the same

two outputs with separate 330Ω current-limiting resistors. These LEDs are driven alternately on and off while the piezo transducer is driven.

They can also be lit independently by holding one output high and the other low; this will only produce a click from the piezo transducer.

The circuit could have been arranged with a single limiting resistor for both LEDs but two resistors have been used so that the PCB layout is symmetrical. A symmetrical cricket is a happy cricket. In other words, the second resistor is required cosmetically but not electrically.

Construction

Kelvin is built on a PCB coded 08109171, measuring 155 x 51mm (but certainly not rectangular!). Fig.2 shows the PCB overlay diagram.

Begin construction by installing the six resistors; use a multimeter to check the value of each before inserting into the PCB. The resistor colour codes for four-band resistors are shown in the parts list but with only four different values, it should be hard to mix them up!

Diode D1 can be installed next, taking care to orient it correctly. The 10nF and 100nF capacitors go in next. These can be oriented either way round but must be in the right spots! Then solder the IC socket for IC1 – note that its notched end faces the 100nF capacitor.

Switch S1 and the 2-way pin header can be installed next, followed by the two PC stakes at the wiring points for the piezo transducer (these stakes mount on the underside of the PCB). Push the cell holder down firmly in place then solder its pins, with its positive terminal oriented towards D1.

LED1 and LED2 are mounted with their lenses pointing diagonally outward toward their respective corners of the PCB and about 3mm off the PCB surface. The exact angle is not important; we bent the leads down by around 45°. The longer lead of each LED must go into the pad marked "A".

The LDR should be mounted about 5mm above the PCB surface and sits horizontally while the thermistor is pushed down fully onto the PCB. Neither of these components are polarised.

The piezo transducer is fitted to the underside of the PCB, supported on TO-220 insulating bushes (used as spacers) and secured with M2 x 8mm machine screws and M2 nuts.

Once it's in place, solder its wires to the PC stakes on the underside of the PCB. The polarity of these wires is not important. Before soldering, slide some short lengths of heatshrink tubing over the wire, then slide them down onto the PC stake connections and shrink them (a heat gun is preferred but we've found a high-power hair dryer on its highest setting should work) to prevent the connections from being stressed and breaking later.

Kelvin's legs and antennae

Kelvin's legs are fashioned from 1.25mm diameter copper wire. Each front leg is 75mm long and the mid and rear legs are each 60mm. These can be as simple or as fancy as you like – the cricket shape printed on the rear of the PCB shows the general shape we used. Bend the legs so that Kelvin will be able to stand raised up from the platform it sits on. The feet are formed as small loops so that sharp ends are not left exposed.

Where the legs are soldered to the PCB, you will need to scrape off the enamel insulation (eg, using a sharp hobby knife or fine sandpaper) before they can be soldered.

Make up the two antennae using 80mm lengths of 0.5mm diameter wire and the ovipositor (tail) with a 40mm length. Once soldered in place, curl the two antenna wires into shape by running a thumbnail along the inside of the radius, with your index finger on the outside.

Check your construction before installing the programmed microcontroller (IC1) in its socket.

If you intend to program the PIC yourself, the firmware (08109171A.HEX) can be downloaded from the SILICON CHIP website. See the programming section below for more details.

Test cricket

Make sure IC1 is oriented correctly (notch in the IC to the notch in the socket) before inserting into its socket. Now

Mode	Temperature indication – Chirp & LED 1-2 pattern	Random chirping	Notes	On power up
1	1 chirp for each °C measured	None	No of chirps = °C	LED2 flashes once
2	1 "chirrrrp" for each 5° + 1 "chrp" for each 1° balance	None		LED2 flashes twice
3	1 "chirrrrp" for each 6° + 1 "chrp" for each 1° balance	None		LED2 flashes three times
4	1 "chirrrrp" for each 10° + 1 "chrp" for each 1° balance	None		LED2 flashes four times
5	1 chirp for each °C measured	During the night	No of chirps = °C	LED2 flashes five times
6	1 "chirrrrp" for each 5° + 1 "chrp" for each 1° balance	During the night		LED2 flashes six times
7	1 "chirrrrp" for each 6° + 1 "chrp" for each 1° balance	During the night		LED2 flashes seven times
8	1 "chirrrrp" for each 10° + 1 "chrp" for each 1° balance	During the night		LED2 flashes eight times
9	1 chirp for each °C measured	During the day	No of chirps = °C	LED2 flashes nine times
10	1 "chirrrrp" for each 5° + 1 "chrp" for each 1° balance	During the day		LED1 flashes once
11	1 "chirrrrp" for each 6° + 1 "chrp" for each 1° balance	During the day		LED1 flashes once; LED2 once
12	1 "chirrrrp" for each 10° + 1 "chrp" for each 1° balance	During the day		LED1 flashes once; LED2 twice
13	1 chirp for each °C measured	Day and night	No of chirps = °C	LED1 flashes once; LED2 three times
14	1 "chirrrrp" for each 5° + 1 "chrp" for each 1° balance	Day and night		LED1 flashes once; LED2 four times
15	1 "chirrrrp" for each 6° + 1 "chrp" for each 1° balance	Day and night		LED1 flashes once; LED2 five times
16	1 "chirrrrp" for each 10° + 1 "chrp" for each 1° balance	Day and night		LED1 flashes once; LED2 six times

Table 1: Kelvin's sixteen modes which enable various measurement parameters and also how his random chirping is controlled. Modes 1, 5, 9 and 13 give 1 chirp for each degree; other modes count the degrees in groups and chirp accordingly. His red eyes flash as he chirps, too.

fit the CR2032 cell in its holder and place the jumper link across the two pins on the 2-way header (JP1).

The initial mode for temperature reporting is mode 1 (see Table 1). When powered, Kelvin first flashes the mode. So, in this case, it will flash LED2 (the ones LED) once to indicate mode 1.

To have Kelvin deliver the temperature reading, press the switch that is labelled "Test Cricket". *[Editor: John, one more cricket reference and "you're out"!]*

The default mode (1) does not include randomly delivered chirps so you will need to change the mode if you want this. Traditionally, since a cricket normally chirps at night, you would want to enable night-only mode. But you can also have day-only random chirps or random chirps at any time. We could even refer to this mode as "day/night test" mode; how's that? *[Editor: safe! But only just...]*

All the modes

Kelvin has 16 possible modes, as shown in Table 1.

There are four sets of four, with each set being identical as far as the chirps and LED flashes go. The difference between the mode sets is the time of day (or more accurately the ambient light level) – Kelvin assumes, arguably correctly, that higher light levels are probably daytime and lower light levels could be night-time; the time when crickets come out to play.

Depending on which mode set is chosen, Kelvin will not randomly chirp at all (modes 1-4); he'll chirp only during the night (modes 5-8); he'll chirp only during the day (modes 9-12) or, the most annoying setting of all, with modes 13-16 chosen he'll randomly chirp at any time, day or night!

The groups of modes also determines what you hear and see as Kelvin measures the temperature. In modes 1/5/9/13 he chirps and flashes once for each degree C he senses.

So if it is 15°C it will chirp 15 times and then stop. The trouble is, it's easy to lose count, especially when the temperature goes higher!

So there are three more modes – and in these cases, Kelvin chirps out the temperature in groups of 5, 6 or 10 respectively. For example, if it's in mode 2, 6, 10 or 14, 17°C will be chirped as two groups – the first of three long chirps, for 15° (5 x 3), the second is two more short chirps for the remainder over 15° (degrees 16 and 17).

Got that? Here's another example: in modes 4, 8, 12 or 16, 23° (counting to ten) Kelvin would give two long chirps (for 20°) and three short chirps (for the remainder).

Modes 5-8 are identical to modes 1-4 except that these modes also enable random temperature chirping at night (ie, when darkness is detected), at intervals of between eight seconds and 29 minutes.

And modes 9-12 are again identical except that in these modes, Kelvin will chirp randomly during the day but not at night. Modes 13-16 are also similar to modes 1-4 but enable random chirping regardless of the light level.

Modes 4, 8, 12 and 16 have an additional feature, where LED1 lights briefly at the start of each group of 10 chirps, while LED2 lights briefly at the start of each single chirp.

Setting modes

Modes 1-4 require the Test Cricket switch (S1) to be pressed in order to initiate any chirping. You can also use this switch in the other modes if you don't want to wait for the random chirping to start.

To change the mode, first switch off power by removing JP1. Then press and hold the Test Cricket switch (S1) and re-insert JP1. Wait until there is a chirp acknowledgement from the piezo transducer and release S1. You can then select the mode by pressing S1 the same number of times as the desired mode.

Kelvin will chirp to acknowledge each press of S1.

If S1 is not pressed, Kelvin will eventually time out and the mode will not be changed. You will hear three chirps to indicate this.

If you do select a new mode using S1, wait and then you should hear two chirps. That indicates that the new mode has been accepted and stored, and will be used from now on. The new delivery format will now be used by Kelvin.

The new mode will then be indicated by flashes from one of the LEDs. For numbers less than 10, LED2 (the ones LED) will flash a number of times.

For modes 10 and above, LED1 (the tens LED) will flash once. Modes above 10 are then indicated by extra flashes from LED2. For example, LED2 will flash once for mode 11 and twice for mode 12.

Modifications

Kelvin has a loud chirp, which can be pretty annoying! If you want to reduce the volume, increase the 100Ω resistor in series with the piezo transducer. Increasing it to, say, 10kΩ will reduce the apparent volume by about 50%. Higher values will provide an even lower volume, to the point where he won't chirp at all.

You shouldn't reduce the resistor to below 100Ω – Kelvin is quite annoying enough, thank you (*especially* at night!).

The light sensitivity (ie, the point at which Kelvin senses light levels) can also be altered, by changing the 470kΩ resistor between the positive supply and the PIC's GP2 input.

Increasing the resistance value (say to 1MΩ) will mean Kelvin reacts to lower daylight levels.

By contrast, reducing the resistance value will mean that more light will be required to detect daytime. If you go too low Kelvin probably won't detect light level changes at all. *(No appealing against the light . . .)*

Programming IC1

If you are programming the microcontroller yourself, note that the PIC12F675 needs special programming due to the fact that it has an oscillator calibration value (OSCAL) that is held at the last location of the PIC's memory. This calibration value is individually programmed into each PIC by the manufacturer and provides a value that allows setting of the PIC to run at reasonably accurate 4MHz rate when using the internal oscillator.

(See Circuit Notebook page 83 of this issue for a detailed explanation on how to set this calibration value).

This value must be read before the chip is erased (in preparation for being re-programmed) so that it can be written back with the rest of the code during programming.

If this procedure is not done correctly, either the PIC won't be programmed or the oscillator frequency could be off. That will have an adverse effect on the realism of Kelvin's chirps.

Most PIC programmers will automatically cater for this OSCAL value (eg, the PICkit 3 does), but it is worthwhile checking if your programmer correctly handles this. SC

TECH FOR YOUR ENTERTAINMENT

UPGRADE YOUR SIGHT & SOUND SYSTEM

Jaycar Electronics

LEARN ABOUT... ...HDMI TYPES

HDMI V1.4 supports refresh rates of 24 to 30fps (frames per second), great for watching movies. HDMI 2.0 supports up to 60fps, great for fast action gaming. Both will support up to 4K high definition video.

$19.95

NEW 2017

3 INPUT HDMI 1.3 SWITCHER AC-1711

Simple switcher to connect 3-inputs (such as a Blu-ray player, media centre, etc) into one display (eg, a TV).

- Ultra-compact
- No external power supply required
- 51(W) x 51(D) x 15(H)mm

$64.95

DIGITAL TO ANALOGUE AUDIO CONVERTER AC-1715

Converts your digital signal into analogue (RCA) stereo audio. Accepts either TOSLINK (optical) or digital coaxial.

- High quality sampling rate
- 63(W) x 42(D) x 26(H)mm

ALSO AVAILABLE:

ANALOGUE TO DIGITAL AUDIO CONVERTER AC-1716 **$64.95**

$84.95

HDMI 1.4 AUDIO EXTRACTOR AC-1741

Extracts the audio from HDMI and outputs to a 3.5mm socket or S/PDIF for connection to a set of active speakers, home theatre audio system or amplifier.

- HDCP support
- 60(L) x 70(W) x 20(H)mm

$179

CAT5/TCP/IP HDMI EXTENDER AC-1734

Extend your HDMI source to a display up to 100m away using CAT5E/6 cable. Suits common home router or switch. IR extender. 1080p. 100(L) x 65(W) x 25(H)mm.

ALSO AVAILABLE:

SPARE TCP/IP HDMI RECEIVER AC-1735 **$99.95**

JUST $69.95

NEW 2017

4K UHD

4 INPUT HDMI 2.0 SWITCHER WITH REMOTE CONTROL AC-1745

Connect your new AV equipment together up to 4 HDMI inputs, and feed them to your flat-screen, projector, or any other HDMI display. Plug and play. Easy to use.

- Remote Control
- Up to 4K2K @ 60Hz
- 128(W) x 75(D) x 20(H)mm

FROM $79.95

4K UHD

AMPLIFIED HDMI 2.0 CABLES

Quality & durable cable designed to avoid any signal loss over the length of the run. Suitable for Full HD, 4K, 3D, and UHD signals.

- 18Gbps 4K @ 60Hz

10M WQ-7437 **$79.95** *Limited stock*

15M WQ-7438 **$99.95**

FROM $59.95

4K UHD

HDMI 1.4 SPLITTERS WITH UHD 4K SUPPORT

Distribute a HDMI source to multiple HDMI displays simultaneously. Supports 4K UHD, 3D video, Dolby-AC3, DSD audio and more.

- Up to 4K @30Hz

2 PORT 2 OUTPUTS AC-1710 **$59.95**

4 PORT 4 OUTPUTS AC-1712 **$109**

NEW 2017

VGA TO HDMI CONVERTER WITH AUDIO AC-1719

Convert your standard VGA output into a digital HDMI signal. USB powered. Plug and play.

- Digital HDMI output
- 3.5mm audio integration

$79.95

$89.95

VGA TO HDMI CONVERTER & UPSCALER AC-1718

Ideal for devices with a VGA output (i.e older laptops) to display on a HDMI device. Also converts analogue audio source into HDMI digital stream.

- HDMI upscaling up to 1080p
- Analogue audio encoding
- 60(L) x 54(W) x 20(H)mm

$39.95

HDMI VOLUME LEVELLER AC-1615

Regulates volume for better listening experience while watching TV. Also helps protect your home theatre equipment from noise spikes. Mains power supply included.

- HDMI in/out ports
- 100(W) x 70(D) x 20(H)mm

4 WAY AV STEREO DISTRIBUTION AMPLIFIER AC-1646

Designed to split a stereo AV signal across 4 channels without loss of image or sound quality. Record up to four sources at the same time. 12V operation. Mains plugpack included.

- RCA and S-Video input & output connectors
- 176(W) x 90(H) x 25(D)mm

$59.95

CLICK & COLLECT AVAILABLE IN STORES

AV MODULES FOR YOUR ARDUINO® PROJECT

$15.95

128 X 128 LCD SCREEN MODULE XC-4629

A compact Colour TFT-LCD supporting 16 bit colour at 128x128 pixels, and only needing six pins for full control.

- SPI interface
- Separate LED backlight control
- 43(L) x 30(W) x 12(H)mm

$29.95

320 X 240 LCD TOUCH SCREEN MODULE XC-4630

Large colourful touch display shield which piggy-backs straight onto your UNO or Mega.

- Fast Parallel interface
- microSD Card slot
- Resistive touch interface
- 77(L) x 52(W) x 19(H)mm

$29.95

128 X 64 MONOCHROME OLED DISPLAY MODULE XC-4384

Monochrome graphics with wide viewing angle.

- I2C interface
- SSD1306 Chipset
- 22(L) x 22(W) x 12(H)mm

AUDIO SHIELDS & MODULES

$3.95

ACTIVE BUZZER MODULE XC-4424

The easy way to add sound to your project. Hook up a digital pin and ground, and use the tone() function to get your Arduino® beeping.

$4.95

AMPLIFIER MODULE XC-4448

For more volume than XC-4424, connect this module to drive a small speaker (up to 3W). The high efficiency Class D amplifier runs happily off 5V.

$7.95

MICROPHONE SOUND SENSOR MODULE XC-4438

Great for any project that needs to detect sounds, XC-4438 has both analogue (for waveform) and digital output with adjustable threshold for simple sound detection.

$9.95

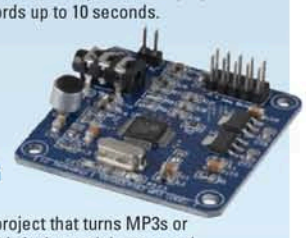
RECORD & PLAYBACK MODULE XC-4605

Includes a small built in amplifier capable of directly driving an 8 Ohm speaker. Ideal if you need to play back a specific sound. Records up to 10 seconds.

$24.95

SI4703 FM TUNER BREAKOUT BOARD XC-4595

Based around one of the IC's commonly used to add FM radio reception to mobile phones and other gadgets, this small module provides a stereo 3.5mm socket for output and is capable of driving headphones directly.



$34.95

MP3 RECORDING MODULE XC-4516

If you want to build a project that turns MP3s or MIDI files into audio, this is the module you need. Pair with an SD card reader module and Arduino to create your own MP3 player.

ADD SOUND TO YOUR PROJECT

All purpose replacement speakers for your project.

FROM $2.95

27MM 80HM 0.25W	AS-3002	$2.95
40MM 80HM 0.25W	AS-3004	$3.50
57MM 80HM 0.25W	AS-3000	$3.95
76MM 80HM 1W	AS-3006	$4.25
50X90MM 80HM 5W	AS-3025	$6.95

See full range available instore or online.

AS-3004 AS-3006 AS-3025

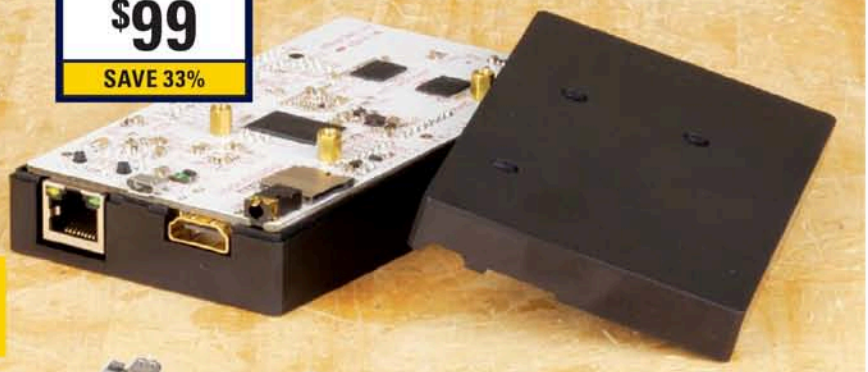
PCDUINO MEDIA PLAYER PROJECT

Create an affordable and functional Media Player using a pcDuino single board computer. We'll show you how to put together a flexible Media Player that can plug straight into your HDMI TV. It can also upgraded with heaps of open source software options available.

NERD PERKS CLUB OFFER
BUY ALL FOR $99
SAVE 33%

VALUED AT $148.75

SEE STEP-BY-STEP INSTRUCTIONS AT: jaycar.com.au/pcduino-media-player



WHAT YOU NEED:

ARDUINO BOARD	XC-4350	$89.95
ENCLOSURE	XC-4354	$19.95
MAINS ADAPTOR	MP-3449	$19.95
USB LEAD	WC-7724	$9.95
HDMI LEAD	WV-7913	$8.95

XC-4350 XC-4354 MP-3449 WC-7724 WV-7913

SEE OTHER PROJECTS AT www.jaycar.com.au/arduino

PROJECT OF THE MONTH

PROGRAMMABLE REMOTE CONTROL

Want to learn more about how IR remote controls can be implemented on an Arduino? - then this project is for you. This Programmable Remote Control is similar to a 'Learning Remote Control', except that it can give a lot more information about the codes it is sending and receiving. Being Arduino based, you can tweak the code and hardware to suit your own project.

Some soldering required!

NERD PERKS CLUB OFFER
BUY ALL FOR $49.95
SAVE OVER 15%

VALUED AT $60.80

SEE STEP-BY-STEP INSTRUCTIONS AT:
jaycar.com.au/prog-remote-control

WHAT YOU NEED:

UNO MAIN BOARD	XC-4410	**$29.95**
PROTOTYPING SHIELD	XC-4482	**$15.95**
28 WAY HEADER STRIP	HM-3211	**$0.85**
470 OHM RESISTOR PACK	RR-0564	**$0.55**
MATRIX KEYPAD	SP-0770	**$8.95**
IR RECEIVER	ZD-1953	**$2.75**
5MM IR LED	ZD-1945	**$1.50**
YELLOW 5MM LED	ZD-0160	**$0.30**

XC-4410

XC-4482

SP-0770

HM-3211

RR-0564

ZD-1953

ZD-1945

ZD-0160

SEE OTHER PROJECTS AT: www.jaycar.com.au/arduino

DON'T FORGET THE MAKER ESSENTIALS

95¢

1.4MM SPST MICRO TACTILE SWITCH SP-0601

- 12VDC 50mA
- Momentary

$4.95

HOOK-UP WIRE PACK WH-3025

2 metres of 8 different colours of 13 x 0.12mm hook- up wire.16 metres in all.

$12.95

ATMEGA 328P IC WITH 16MHZ CRYSTAL ZZ-8727

Comes with the Arduino® UNO bootloader pre-installed.

BREADBOARD LAYOUT PROTOTYPING BOARDS

A fantastic way to transfer your concept breadboard design to PCB without having to go to the trouble of designing and making a PCB. Includes five holes on each side per row and power rails running the length of the board. Two sizes to choose from.

SMALL

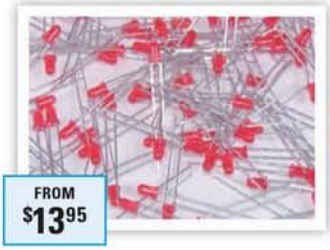
- 25 rows, 400 holes
- 73mm x 47mm x 1.4mm

HP-9570 **$4.95**

LARGE

- 59 rows, 862 holes
- 155mm x 58mm x 1.4mm

HP-9572 **$9.95**



FROM $13.95

LED PACK

5-20mcd @ 20mA. Packet of 100. Red.
3MM ZD-1692 **$13.95**
5MM ZD-1690 **$17.95**

$13.95

LED TESTER AA-0274

Checks function, brightness, colour and polarity of light emitting diodes (LED).

- Test currents: 1mA, 2.5mA, 5mA, 10mA, 20mA,50mA

$19.95

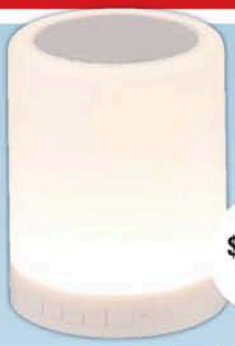
BREADBOARD WITH POWER SUPPLY PB-8819

830 tie-point breadboard with removable power supply module. Includes 64 mixed jumper wires of different length and colour.

- 3V and 5V switchable output

PLAY MUSIC WIRELESSLY WITH BLUETOOTH®

AT HOME Bluetooth



LED LAMP SPEAKER XC-5228

Features a rechargeable battery so you can put it just about anywhere. Also has 3.5mm socket for direct audio source or playback from the microSD card.

- Recharges via USB (cable supplied)
- 121(H) x 96(Dia.)mm

$29.95

$79.95

SOUNDBAR TV SPEAKER XC-5226

Provide high quality audio for your TV viewing pleasure. Dual two-way speakers. Power supply included. 810mm wide.

- Bluetooth® or wired connectivity
- Remote & onboard controls

$54.95

WIRELESS AUDIO RECEIVER WITH NFC AA-2108

Stream music from your Smartphone or Tablet directly to your stereo system or stand-alone speakers wirelessly. Mains powered. 58(L) x 58(W) x 15(H)mm

- Supports NFC enabled devices

$69.95

AUDIO DONGLE AA-2104

Stream an audio source to a Bluetooth® capable receiver/speaker. Includes internal rechargeable battery. Ultra-portable.

- Send / Receive mode selection
- 44(W) x 44(D) x 12(H)mm

IN THE CAR Bluetooth

VISOR MOUNT RECHARGEABLE CAR KIT AR-3134

Safe to make and receive mobile phone calls whilst driving. Built-in microphone, high powered loudspeaker, and dual standby allowing two phones to connect simultaneously.

- Sunvisor holder, USB cable and 12V car charger included

$39.95

$29.95

SMART PHONE MEDIA BUTTON AR-3137

Remotely control volume, play/pause and tracks on your paired device. Steering wheel bracket included.

$29.95

MINI RECEIVER WITH USB CHARGING AA-2105

Stream from your phone to car radio with 3.5mm stereo input. Built-In microphone for hands-free calls. Echo and noise cancelling.

IN-CAR EARPIECE WITH USB CHARGER AR-3135

Provides hands free communication.

- Magnetic charging dock
- USB 2.1A and 1A charging ports

$39.95

OUT LOUD Bluetooth

$99

STEREO AMPLIFIER WALLPLATE AA-0519

Replace that bulky amplifier powering your outdoor or ceiling speakers with this clever wallplate. Stream music from your Smartphone or connect audio to the AUX input. Includes 12V mains adaptor.

- 2 x 15WRMS (4Ω) Class-D amplifier

Limited stock

$179

10" PORTABLE PA SPEAKER WITH MP3 PLAYER CS-2483

2 way 100WRMS speaker produces great clarity and powerful bass. Strong and durable moulded enclosures with tough metal grille. Stream music from your phone or play from a USB/SD card. Mains powered.

FROM $249pr

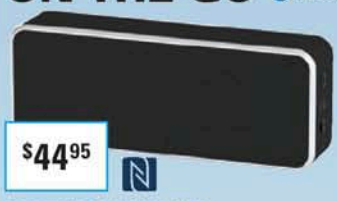
2 WAY ACTIVE PA SPEAKERS

Indoor and outdoor active stereo speakers. Utilising powerful woofers and good quality silk dome tweeters. Mains powered.

5.25" 30WRMS CS-2470 **$249**

6.5" 50WRMS CS-2472 **$299**

ON THE GO Bluetooth



$44.95

PORTABLE SPEAKER WITH NFC XC-5209

Great sounding portable speaker with microphone for hands-free calls.

- Supports NFC enabled devices
- Aux in, 3.5mm stereo socket
- Rechargeable

$49.95

GREAT SOUNDING HEADPHONES AA-2134

Stream music to these headphones freeing you from annoying cables. Works as a handsfree device too.

- Built-in microphone
- Rechargeable

$29.95

SPORTS EARPHONES AA-2135

Exceptionally lightweight and provides quality audio without any cables! Accept or reject calls, control music playback and volume.

- Rechargeable

$44.95

AUDIO RECEIVER WITH MUSIC CONTROL AA-2087

A clever and convenient way to listen to your music or take calls on the go without having to be tethered to your phone or Tablet.

- Rechargeable

TECH TIP

DISPLAYPORT VS HDMI:

Your TV, computer, Blu-ray player, etc., will most likely have a HDMI (High Definition Multimedia Interface) connector. A few devices, however, have an alternative interface called DisplayPort. HDMI and DisplayPort essentially enable you to connect your device to a TV or monitor. So what is the difference between them? … The first difference is the type of connector, you will need a different cable for HDMI or DisplayPort. You can easily convert between DisplayPort to HDMI using the Jaycar DisplayPort to HDMI cable (WQ-7443), or the DisplayPort to HDMI converter adaptor (WQ-7422).

There are three types of HDMI connectors (full size, mini and micro), as well as two types of HDMI cables; standard (HD video), and high resolution (4K video). DisplayPort, on the other hand supports 4K video as a standard, and comes in two types of connectors; full size or mini.

HDMI has a feature called Audio Return Channel (ARC) that can send the audio from your TV to your Home Theatre amplifier, while DisplayPort does not provide this feature but does allow you to connect multiple screens (each with their own display) to a single DisplayPort (using an appropriate breakout adaptor) - that's a pretty useful feature for commercial applications or for avid gamers.

DisplayPort allows you to connect multiple screens

HDMI can send audio from your TV to your Home Theatre amplifier

DISPLAYPORT

$29.95 ea

MINI DISPLAYPORT CONVERTER LEADS

Connect modern computers with a Mini DisplayPort® to a VGA, HDMI, DVI equipped monitor or projector. Up to 1080p resolution. 1.8m long.

VGA CONVERTER WQ-7440
HDMI CONVERTER WQ-7442
DVI CONVERTER WQ-7444

FROM $19.95

DISPLAYPORT TO DISPLAYPORT LEADS

Used to connect a video source to a display device such as a computer monitor.

PLUG TO PLUG 1.8M WQ-7450 **$19.95**
PLUG TO PLUG 3.0M WQ-7452 **$29.95**
PLUG TO MINI PLUG 1.8M WQ-7454 **$29.95**

$39.95

MINI DISPLAYPORT TO DISPLAY PORT/HDMI/DVI CONVERTER

WQ-7427

Easily converts to high definition displays that take HDMI, DVI or DisplayPort. Fully powered from the mini DisplayPort of your input device. 1.8m long.

$34.95

3M MINI DISPLAYPORT TO HDMI LEAD WQ-7443

Connect your Mac® to a high definition display with this mini display HDMI lead.

- Designed for Mac® computers
- Plug and play

$59.95

USB 3.0 TYPE-C TO DISPLAYPORT CONVERTER

XC-4971

Designed to convert an existing DisplayPort signal to a new USB Type-C connector. Delivers up to 4 x 2K resolution depending on the application.

- 43(L) x 43(W) x 13(D)mm

NOW $79.95
SAVE $20

2 WAY DISPLAYPORT SWITCHER AC-1757 WAS $99.95

Allows you to select between two signal sources to send to a single monitor. Includes a mains power adaptor.

- 71(L) x 61(W) x 21(H)mm

ALSO AVAILABLE:

2 WAY DISPLAYPORT SPLITTER AR-1755
WAS $99.95 NOW $79.95 SAVE $20

HDMI

$24.95

IN-LINE HDMI ESD PROTECTOR

AC-1738

Protect HDMI port against static shocks, surges and lightning strikes.

- HDCP compliant/EDID pass through
- 39(H) x 20(W) x 11(D)mm

$8.95

NEW 2017

BARGAIN HDMI 2.0 CABLE

WV-7913

High quality 1080p vision. Full HD compatible.

- 1.5m long

FROM $9.95

HDMI ADAPTORS

Connect a standard HDMI lead to devices with other HDMI compatible connections.

MICRO HDMI PLUG TO HDMI SOCKET
PA-3649 **$9.95**
MINI HDMI PLUG TO HDMI SOCKET
PA-3645 **$9.95**
HDMI SOCKET TO DVI-D PLUG
PA-3644 **$14.95**
HDMI PLUG TO DVI-D
PA-3642 **$14.95**
HDMI SOCKET TO SOCKET
PA-3640 **$16.95**

$34.95

USB POWERED HDMI REPEATER

AC-1703

Amplifies the signal and extends the distance of HDMI cables up to 35m.

- HDCP Passthrough
- Supports 3D & High Definition
- 52(L) x 26(W) x 13(H)mm

$129

HDMI 4 X 2 MATRIX SWITCHER SPLITTER WITH UHD 4K SUPPORT AC-1714

Distribute up to four HDMI sources to 2 displays simultaneously. Remote control included.

- Supports 12 bit per channel deep colour
- Resolution up to 4Kx2K

$27.95

HDMI TO VGA + STEREO AUDIO CONVERTER AC-1724

Connect newer HDMI source like a laptop or Blu-ray player to a VGA display. Also convert the audio stream from HDMI to analogue audio which can be output to some speakers or headphones.

WORKBENCH ESSENTIALS

There has been an obvious resurgence in people getting back to the workbench and reviving skills involving manual dexterity. As you will see across the following pages, Jaycar has all the DIY tools you'll need to equip your workbench so you can create projects from the power of your brain and your hands.

1. PORTASOL SUPER PRO GAS SOLDERING TOOL KIT TS-1318 **WAS $129**
- Quality Portasol® Super Pro Iron
- Includes tips and cleaning sponge/tray
- Storage case

2. F-TYPE REMOVAL TOOL
TD-2000
- Insert/unscrew F-Type or BNC connectors
- Comfortable grip
- Carbon steel
- 255mm long

3. PRO SOUND LEVEL METER
QM-1592 **WAS $379**
- A & C weighting scales
- External calibrator
- Over and under-range display
- Analogue outputs
- Fast and slow response

4. RATCHET CRIMPING TOOL FOR BNC/TNC CONNECTORS
TH-1846
- Heavy duty
- For crimping BNC/TNC connectors onto RG58/59/62 coax cable

5. 20MHZ USB OSCILLOSCOPE QC-1929
- Ultra portable
- Automatic setup
- Waveforms can be exported as Excel/Word files
- Spectrum analyser (FFT)
- Includes 2 x probes

6. 30M SPEAKER CABLE
WB-1709 **WAS $32.95**
- Heavy duty
- 24/0.20mm Figure 8 with trace

CARPET CABLE COVER

Conceal unsightly cords and eliminate trip hazards. Re-usable over 1000 times, machine washable. Use on any nylon based carpet. 100mm wide.

PER METRE:

BLACK HP-2000 **$9.95/m**
YELLOW HP-2002 **$9.95/m**

5M ROLL:

BLACK HP-2004 **$46.95**
YELLOW HP-2006 **$46.95**

BRAIDED HOOK AND LOOP LOOM WRAP

A fantastic solution for keeping cables wrapped up and neatly arranged. Wraps around your cables and secures them with hook and loop.
- Polyester material
- 1.5m long

32MM WH-5654 **$14.95**
51MM WH-5656 **$17.95**

FROM $14.95

$99.95

DIGITAL INDOOR/OUTDOOR TV ANTENNA LT-3137

Provides high quality clear TV reception. needed. Wall mounted. AC adaptor included.

$89.95

TV SIGNAL BOOSTER LT-3253

Supports all analogue and digital TV signals. 4 outputs to boost the antenna signal all over your house. Includes AC power injector.

$19.95

4G/LTE FILTER - F TYPE LT-3067

Designed to fit in-line with an F-type coaxial cable. Removes cell phone interference from your TV signal.

FROM $12.95

SPLITTERS WITH POWER PASS

Features power pass on the input to one output, which allows power to pass to a masthead amplifier or satellite dish LNA.

2-WAY LT-3046 **$12.95**
4-WAY LT-3047 **$17.95**

$89.95

HIDDEN CAVITY MEDIA BOX

CW-2879

Designed to be mounted in a cavity / stud wall and holds up to five wall plates.
- 285(W) x 250(H) x 70(D)mm

$19.95

ROTARY COAX STRIPPER TH-1820

Handy stripper that will strip the outside jacket and inner conductor in one operation. Quality stripper suited to installers.
- Suitable for RG58/59/62/6 and 3C2V 75 ohm cable

$44.95

30M ANTENNA CABLE WB-2014

High quality quad-shielded cable between your antenna and TV. RG6.

$14.50

ULTIMATE HEATSHRINK PACK

WH-5520

1 length each of 7 different colours in 7 different sizes ranging from 1.5mm dia to 20mm.
- Sizes: 1.5, 3, 5, 6, 10, 16 & 20mm

$3.95

75 OHM TV FLOOR SOCKET WITH F59 CONNECTION LT-3063

Designed to mount on the skirting board or floor.
- Mounting screws included

EXCLUSIVE CLUB OFFERS:

FOR NERD PERKS CLUB MEMBERS

WE HAVE SPECIAL OFFERS EVERY MONTH. LOOK OUT FOR THESE TICKETS IN-STORE!
NOT A MEMBER? Visit www.jaycar.com.au/nerdperks

NERD PERKS CLUB OFFER

SAVE 25%

USB MIDI INTERFACE
XC-4934
WAS $29.95 SAVE $8
NOW ONLY $21.95

NERD PERKS CLUB OFFER

BUNDLE DEAL

HDMI EXTENDER BUNDLE
1 X EXTENDER
AC-1730
2 X 20M CAT6 CABLE
YN-8298
VALUED AT $144.85
SAVE $25.85
ONLY $119

NERD PERKS CLUB OFFER

BUY 1 GET 2ND AT

HALF PRICE

RESPONSE WOOFERS 4"–12"
Need two of the same woofer? Buy one, and grab a second identical woofer for half price.

SAVE 25%

4" CW-2190 **$24.95ea**
5" CW-2192 **$29.95ea**
6.5" CW-2194 **$34.95ea**
8" CW-2196 **$39.95ea**
10" CW-2198 **$64.95ea**
12" CW-2199 **$79.95ea**
e.g. CW-2190 Buy 1 for $24.95, get the second for $12.48 = $37.43 (Normally $49.90, Save $12.48)

NERD PERKS SAVE 25%

3 PIN XLR TYPE TO RCA ADAPTOR
PA-3800 **REG $9.95 CLUB $7.45**
Metal construction.

NERD PERKS SAVE 25%

FREEZING SPRAY
NA-1000 **REG $19.95 CLUB $14.95**
250g.

NERD PERKS SAVE 30%

THIN BALL BEARING COOLING FAN
YX-2518 **REG $28.95 CLUB $19.95**
120mm 12VDC.

NERD PERKS SAVE 20%

FUSE PACKET OF 40
SF-2240 **REG $12.95 CLUB $9.95**
3AG 500mA-10A.

NERD PERKS SAVE 10%

2, 6, 12V LEAD ACID BATTERY CHARGER
MB-3518 **REG $24.95 CLUB $21.95**
600mA.

NERD PERKS SAVE 30%

SEALED ABS ENCLOSURE
HB-6120 **REG $5.95 CLUB $3.95**
64(L) x 58(W) x 35(H)mm.

NERD PERKS SAVE 20%

DIODE 1N4007 1000V 1A D041
ZR-1008 **REG $12.95 CLUB $9.95**
Pack of 100.

NERD PERKS SAVE 15 %

MEGA PROTOTYPING BOARD SHIELD
XC-4482 **REG $15.95 CLUB $12.95**
68(L) x 53(W) x 12(H)mm.

NERD PERKS SAVE 25%

CRO PROBE CABLE
QC-1902 **REG $39.95 CLUB $29.95**
1:1/10:1 Black.

NERD PERKS SAVE 25%

ALPHANUMERIC DOT MATRIX LCD MODULE
QP-5516 **REG $19.95 CLUB $14.95**
2 line LCD.

NERD PERKS SAVE 15%

CCD CAMERA EXTENSION CABLE
WQ-7275 **REG $19.95 CLUB $16.95**
5 metres.

NERD PERKS SAVE 25%

TWEEZER SET
TH-1760
REG $19.95 CLUB $14.95
Stainless steel. ESD safe.

NERD PERKS CLUB MEMBERS RECEIVE:

20% OFF

XLR & CANNON CONNECTORS*

**INCLUDES AMPHENOL XLR PLUGS & SOCKETS, MINI XLR PLUGS & SOCKETS*

YOUR CLUB, YOUR PERKS:
NEW OFFERS EVERY MONTH!
$1 = 1 POINT, 500 POINTS = $25 JAYCOINS GIFTCARD
Conditions apply. See website for T&Cs

WHAT'S NEW

WE'VE HAND PICKED JUST SOME OF OUR LATEST NEW PRODUCTS. ENJOY!

PORTABLE ACTIVE 15" 300W PA SPEAKER WITH TWO UHF MICS CS-2491

Music streaming via Bluetooth®, or via SD/USB.

- 2 x wireless microphoones
- Mains powered

2 X 10" PA SPEAKER SYSTEM WITH 2 UHF MICROPHONES CS-2566

Fully featured stereo PA system with plenty of power and functionality.

- 8-Channel mixer with 2 x 50W amplifier
- 2 x wireless microphones

COMPACT STEREO AMPLIFIER AA-0518

2 x 20WRMS for powering speakers anywhere you like.

- Gold plated terminals
- Master volume control

GALVANIC ISOLATION FILTER AA-3075

Remove hum from your audio system and enjoy the music properly! No power required.

- Can be wall-mounted
- Gold-plated RCA sockets

TOSLINK JACK TO 2X TOSLINK JACK PA-3512

Used to split a signal to two receivers.

- Works in either direction
- No power required
- Ultra compact

MULTI-FUNCTION CRIMPING TOOL TH-1807

Provides interchangeable dies to crimp RCA, BNC, PAL and F-Type connectors with ease.

- Metal construction
- Die-holder included

5 PORT USB DESKTOP CHARGER MP-3439

Charge and power up to 5 USB devices at the same time! High Current 2.4A Charging. Integrated desktop stand.

- 5V @ 8A (Total)
- 117(W) x 23(H) x 78(D)mm

BATTERY ISOLATOR SWITCHES WITH AFD

Durable and rated for massive output. Features Alternator Field Disconnect (AFD) which protects your alternator when switching batteries in and out of the circuit. Rated up to 48VDC.

275A	SF-2249	**$39.95**
200A DUAL BATTERY	SF-2250	**$49.95**

UNIVERSAL BALANCE CHARGER MB-3629

Economic and high quality charger, capable of balance charging 2-4 cells (LiPo/LiFe/LiHV) or 6-8 cells (Ni-MH) batteries. Mains powered.

- Individual cell monitoring
- 50W/4A max charging current

NOTICED SOMETHING DIFFERENT?

You'll have noticed that store details have disappeared on this page. With over 100 stores across Australia & New Zealand, we can no longer fit them into the space allocated, instead - we are going to use the space to highlight NEW products. If you are looking for store details please visit **www.jaycar.com.au** or call **1800 022 888**

TERMS AND CONDITIONS: REWARDS / NERD PERKS CARD HOLDERS FREE GIFT, % SAVING DEALS, DOUBLE POINTS & MEMBERS OFFERS requires ACTIVE Jaycar Rewards / Nerd Perks Card membership at time of purchase. Refer to website for Rewards/Nerd Perks Card T&Cs. PAGE 2: Nerd Perks Card holders receive special price of $99 for pcDuino Media Player Project (1 x XC-4350 + 1 x XC-4354, 1 x MP-3449, + 1 x WC-7724, & 1 x WV-7913) when purchased as bundle. PAGE 3: Nerd Perks Card holders receive special price of $49.95 for Programmable Remote Control Kit (1 x XC-4410 + 1 x XC-4482, 1 x HM-3211, + 1 x RR-0564, & 1 x SP-0770, 1 x ZD-1953, 1 x ZD-1945 & 1 x ZD-0160) when purchased as bundle. PAGE 7: Nerd Perks Card holders receive special price of $119 for HDMI Extender (1 x AC-1730 & 2 x YN-8298) when purchased as bundle. Nerd Perks Card holders Buy 1 Response Woofer and Get 2nd at Half price applies to CW-2190, CW-2192, CW-2194, CW-2196, CW-2198 and CW-2199. Nerd Perks Card holders receive 20% OFF XLR & Cannon Connectors applies to Jaycar 300H XLR/Cannon Connectors product category.

NEW STORE: MALAGA

1/1890 Beach Rd, Malaga, 6090 WA
PH: (08) 9248 3613

FOR YOUR NEAREST STORE & OPENING HOURS:

1800 022 888

www.jaycar.com.au

92 STORES & OVER 140 STOCKISTS NATIONWIDE

Jaycar Electronics

Head Office
320 Victoria Road,
Rydalmere NSW 2116
Ph: (02) 8832 3100
Fax: (02) 8832 3169

Online Orders
www.jaycar.com.au
techstore@jaycar.com.au

Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock. Savings off Original RRP. Prices and special offers are valid from Catalogue Sale 24 September - 23 October, 2017.

SEE HOW TO USE IT IN SILICON CHIP JAN 2016 (or at siliconchip.com.au)

THIS CHART will become as indispensable as your multimeter!

- Huge A2 size (594 x 420mm)
- Printed on 200gsm photo paper
- Draw on with whiteboard markers (remove with damp cloth)
- Available flat or folded

SILICON CHIP .COM.AU

REACTANCE - INDUCTANCE - CAPACITANCE - FREQUENCY READY RECKONER

How good are you at remembering formulas? If you don't use them every day, you're going to forget them!

Things like inductive and capacitive reactance? Series and parallel L/C frequencies? High and low-pass filter frequencies?

This incredibly useful reactance, inductance, capacitance and frequency ready reckoner chart means you don't have to remember those formulas – simply project along the appropriate line until you come to the value required, then read off the answer on the next axis!

Here at Silicon Chip, we find this the most incredibly useful chart ever – we use it all the time when designing or checking circuits.

In fact, it's so useful we decided our readers would love to get one, so we printed a small quantity – just for you!

And here it is: printed a whopping A2 size (that's 420mm wide and 594mm deep) on beautifully white photographic paper, ready to hang in your laboratory or workshop.

If you don't find it as useful as we do, we'll be amazed! In fact, we'll even give you a money-back guarantee if you don't!#

Order yours today – while stocks last. Your choice of: Supplied fold-free (mailed in a protective mailing tube); or folded to A4 size and sent in the normal post.

But hurry – you won't believe you have done without it!

#Must be returned post paid in original (ie, unmarked) condition.

Read the feature in January 2016 Silicon Chip (or view online) to see just how useful this chart will be in your workshop or lab!

NOW AVAILABLE, DIRECT FROM www.siliconchip.com.au/shop:

Flat – (rolled) and posted in a secure mailing tube $20.00 ea inc GST & P&P*

Folded – and posted in a heavy A4 envelope $10.00 ea inc GST & P&P*

***READERS OUTSIDE AUSTRALIA:** Email us for a price mailed to your country (specify flat or folded).

ORDER YOURS TODAY – LIMITED QUANTITY AVAILABLE

SERVICEMAN'S LOG

Old-fashioned appliance repairs still worthwhile

Dave Thompson*

As mentioned before in this column, I've recently started advertising for different types of repair work. As normal service work continues its inevitable decline, other opportunities come knocking.

I don't mean opportunities like some talent scout discovering me and offering me a movie deal (though of course this might still happen). I'm talking about opportunities that come about because I've been putting myself out there; shaking the trees to see what falls out, as it were.

There are many home-based businesses in Christchurch these days, because of the post-quake lack of suitable buildings and profiteering on what little usable space is still available. Hundreds of businesses down-sized into converted garages and porta-cabins, turning them into design studios, beauty salons, paint booths or in my case, a computer repair workshop.

But the council, who claimed to be 110% behind the rebuild, threw up so many unnecessary roadblocks to small business owners that many simply didn't bother reopening.

For example, I plopped a 10m^2 porta-cabin on our front lawn from which to temporarily operate. I was advised by the people selling and renting portable structures that this was the largest building I could install without needing planning consent. However, in my naivety, I neglected to put it further than four meters from the street boundary of my property.

It transpired that in order to operate a business in a portable structure within this distance from the street, I had to jump through all manner of bureaucratic hoops. First, I had to get the permission of all the neighbours in

my street and the surrounding streets. I also had to declare the date by which I would vacate the temporary premises.

Obviously, I'd need to get out my crystal ball because at the time, nobody had any idea of how long it would take to get back to normal. In the end, I had to agree to move out from my new workshop after just 12 months, making the cost and worth of doing all this a lot less appealing than it had seemed initially.

The council apparently weren't all black-hearted though; they did make some concessions to allow us to operate from our temporary workshops. For example, we were allowed five times the size of the normal regulation signage for businesses in residential areas. At least we could advertise our presence to potential customers!

But then I learned that the original maximum sign size was a whopping 200 x 60mm and the council, in its infinite generosity, would now allow us up to 200 x 300mm. That's less than the size of an A4 sheet of paper. Overwhelmed with their generosity and spirit, I indeed did put up an A4-sized poster.

I asked the humourless inspector who came to check (Oh yes, they checked) if I could put the 4 x 3 metre sign from my original workshop on my garage door, which was down the drive a fair way from the street or on the roof of the cabin instead and was told "no!". If that sign was visible from anywhere (including from the air!) they would prosecute; unbelievable, but true.

Luckily though, there is a relatively new website over here designed to bring communities closer together. This helps neighbours who may not know each other; to introduce themselves and their families and assist in keeping everyone in touch with what's happening around them.

The ultimate goal is to try and get back some of that community feel we had in the "old days", where everybody knew and looked out for each other. But it has also turned out to be a great place to let neighbours know about the numerous small businesses lurking within their midst.

This was a bit of a blessing, so I put my details out there at the earliest opportunity. And as we have a school entrance across the road, having even minimal external signage might catch the attention of school-run parents.

As a result, I've had a few computer repair jobs but the biggest response was from an article I posted responding to someone asking about appliance repairs. I didn't say I fixed appliances but instead posted a response agreeing with someone who was lamenting throwing out an appliance because repair companies aren't particularly interested in fixing them any more, preferring instead to sell a new unit.

I offered to take a look and in the meantime, the original post gained some traction, with many posts from people dissatisfied with other repair guys. At that point, I flagged my interest in having a look at some of these broken appliances with an eye to repairing them. I suggested that I would assess first before advising the customer about the potential costs involved and then they could decide whether to proceed.

Since then I've had an array of blenders, stereos, a turntable, desktop ovens, coffee machines and a couple of cordless drills to look at; and I couldn't be happier!

Variety is the spice of life, or so they say. I certainly enjoy the challenge that some of these devices bring to the workshop. Most can be fixed, relatively inexpensively, with many not even requiring spare parts; just a little creative fettling to get them back to serviceability.

Diagnosing a sick blender

For example, one neighbour dropped off an older-style blender for me to have a look at. She complained that it only worked intermittently, though when it did work, it worked very well.

Items Covered This Month

- Blender repair
- Fixing a MacBook Air laptop

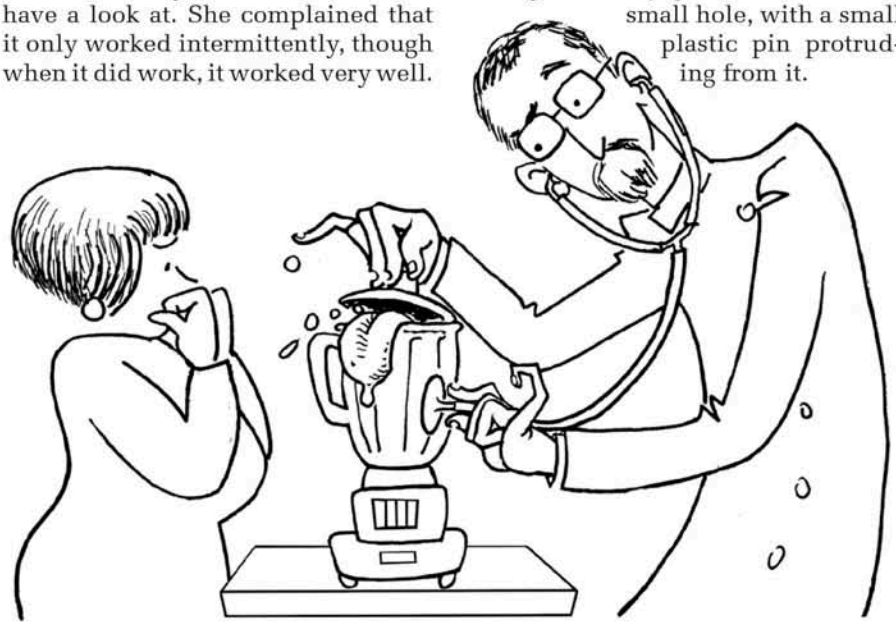
*Dave Thompson runs PC Anytime in Christchurch, NZ.
Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

She'd taken it to another outfit and they'd told her it was past it and she needed a new one, then charged her $45 for the privilege.

She suspected those guys hadn't even looked at it and felt certain the blender just had a loose connection or faulty switch. It was a good unit; a quality brand with a very heavy, polished cast-aluminium base and a thick Arcoroc jug. It was clearly built to last and to be repaired, and was still in good condition if a little dirty.

When she dropped it off, she mentioned that she thought the switch might be the problem as it sometimes didn't feel solid in operation. The first thing I did was plug it in and switch it on. Nothing happened, though of course, it wouldn't, as I didn't have the jug attached.

Most higher-end blenders have a safety-switch arrangement that disables the motor power if there is no attachment present or it is not fully twisted home. This prevents things potentially getting messy. On the top of the heavy base, right next to the cast fittings for the jug to screw into is a small hole, with a small plastic pin protruding from it.



DIAGNOSING A SICK BLENDER

When I manually held this pin down, I could feel and hear a microswitch inside the blender actuating. With this switch actuated and the blender switched on, the motor kicked into life. I tried it a few more times and every time the pin was pushed in, the motor fired up.

I toggled the main switch back and forth but it seemed solid. I suspected that this pin was the issue; it had worn down over the years so that it was now barely flush with the raised metal housing. It must be very close because with the jug in, sometimes it worked and sometimes it didn't, leading the owner to think (quite sensibly) that the switch was failing.

What amazed me was that those other repair guys hadn't spotted this most obvious of problems. Or perhaps they did and just couldn't be bothered doing the work; I don't know. To my mind, this would be relatively easy to repair. I contacted and quoted the customer and when she happily agreed, I set about fixing it.

Chalk one up for Dave

I considered extending the pin or grinding the metal shroud down around the pin, exposing more of it, but that seemed a bit barbaric and I wanted to see how it worked inside first.

The only way in was through the bottom and of course it had some of those horrible Torx-style security screws holding the base on. These are the type with a small pip in the centre, making it impossible for a standard Torx driver to get purchase onto the screw head. They'd made it even harder by sinking the screws into the plastic bottom housing by about 40mm, with a relief diameter smaller than a standard bit-holding driver shaft.

This meant that normal drivers and bits, like the one I use, had no chance of getting anywhere near the screws. However, I tried the bit by itself and it did fit down there, so I took it out and stuck it in my metal-working vise. I then fitted my Dremel with a 0.5mm cutting disc and cut a small channel in the bottom large enough for a small flat head screwdriver to fit into.

After cleaning up the cut, I returned the bit to the first hole and after a bit of positioning, simply used my screwdriver to undo it. I refuse to be beaten by these manufacturers with their stupid security fasteners. There is always a way around them, so why bother with them?

Once the bottom was off, the motor and switching arrangements were revealed. I checked the brushes and they appeared to be about half worn, with plenty of life left. The motor was certainly a chunky unit, leaving little room for anything else inside the case.

I shone a light down the side and could see the plastic safety switch. It looked like a simple plastic piece sandwiched between the microswitch, which was mounted on the motor's field windings cage, and the inside top of the case. If the pin was pushed down from the top, that pressure transferred directly to the toggle of the microswitch; simple yet very effective.

To get it out, I'd have to move the motor and this involved removing four screws, two of which were partially obscured by wiring and the main switch body. At least these screws had standard Phillips-style heads on them, so I could use a long, thin driver to angle around the switch housings and field windings to get to the screws and get them out.

I briefly considered removing the hard-rubber drive arbor but decided against it. It appeared to be moulded on and I was afraid if I did get it off, I might not be able to get it back on again (not for the first time). I did try unscrewing it with my hands, both ways, and had a go gently levering a couple of large-bladed screwdrivers underneath it but it didn't give at all so I gave up. Knowing when to stop is part of the game.

With the four screws out, I was able to jiggle the plastic switch toggle out. As I suspected, it was simply a bit of injection-moulded Nylon and the pin had worn down over time. There was no way to make it bigger; I considered swapping the pin for a screw, but that might end up chewing out the plastic bottom of the jug, so in the end I decided to build it up underneath.

There was some play where it touched against the microswitch and building it up would cause the pin on the other side to poke through the case a bit more. I did this by first drilling out the raised plastic area that touched the switch, a 6mm-diameter circular moulding that protruded 3mm toward the switch toggle.

Using a PCB drill, I drilled four holes into the round block. I then created a turret-shaped mould with heavy masking tape around the block and mixed up some 24-hour epoxy to fill it with. I had to heat the epoxy up a bit with my heat gun as it was too cold for it to run very well. Once warm though, it was quite liquid, and using a cotton bud I dripped the epoxy slowly into the small mould.

I was careful to avoid getting bubbles in it and manipulated it to ensure the holes were filled. The next day, I removed the tape and with needle files, shaped the area to match the rest. When I reassembled everything, the pin protruded about 1mm from the top; more than enough for the jug to actuate the switch. A good fix, and one less appliance needlessly thrown away. A win-win, as they say.

Repairing a badly broken 13-inch MacBook Air

B. R., of Seven Hills, NSW has taken to repairing Apple Mac laptops. These can be a challenge but he has some handy tips in this next story...

Over the past few months I've been occupying my spare time repairing broken Apple Mac laptops. I'm not actually a computer repairer; I just buy broken Apple MacBooks at a discounted price on eBay, repair them and then re-sell them (or sometimes I just keep them for myself).

I don't do it to earn money, I just do it as a hobby so any money made is an added bonus. Here's an account of my latest MacBook repair, as well as some of the important component-level repair information I have learned.

Firstly, I'm very selective about what I will repair and I prefer laptops rather than desktop computers. Most desktop computers in need of repair get sold without a keyboard and mouse. So if I am planning to re-sell them as a com-

Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?

We pay for all contributions published but please note that your material must be original. Send your contribution by email to: editor@siliconchip.com.au

Please be sure to include your full name and address details.

plete package, I have to factor in the cost of a new keyboard and mouse. And if I have a few repairs on the go at any given time, the laptops are far easier to store.

Another important factor is the resale price. Laptops seem to hold their second-hand value much better than their desktop counterparts, so that gives me a better chance of selling for a profit. I stick to Apple Mac laptops because they usually sell for more than an equivalent Windows laptop and there seems to be a good supply of second-hand and after-market replacement parts.

And finally, laptops seem to get damaged by liquid quite often, which is usually easy to repair. Most of the broken laptops I come across fall into three categories: liquid damage, cracked screens and failed graphics chips. I usually steer clear of the last two and try to buy the liquid-damaged laptops as often as possible.

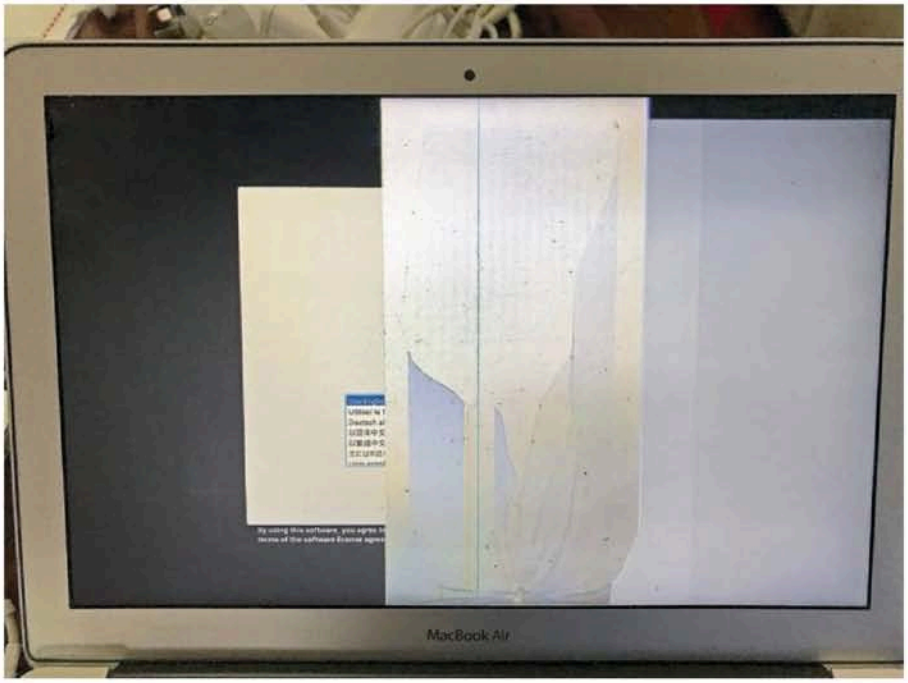
It really is quite extraordinary how many laptops end up with some sort of liquid being spilled on them. I certainly can't judge, as I have given my keyboard a drink from time to time. Not all spills mean the instant end of a laptop, but corrosion can build up on the liquid-affected parts, and one day the laptop might just stop working.

Computer manufacturers typically won't do any component-level repairs. If you have a corroded component on the computer's motherboard, they will replace the whole motherboard. Depending on the age of the computer, that can easily cost more than the device is worth and that's why they regularly end up for sale on eBay at cheap prices.

Some repairs aren't as easy as expected

I recently purchased a 13-inch MacBook Air on eBay, with the symptoms described as "Laptop does turn on however runs very slowly". I know from experience that with a MacBook Air, this is usually caused by a faulty sensor and I know that faulty sensors are often caused by corrosion from liquid damage. And corrosion is usually easy to see on the motherboard.

The laptop was going for a pretty low price and the repair would (hopefully) be fairly inexpensive, so this one seemed like a good candidate. I made the purchase and waited for it to arrive. A couple of days later, my friendly neighbourhood delivery man arrived at my front door with the "new" laptop.



This peculiar fault is caused by the cracks in the screen of the MacBook Air laptop. This was the initial bootup screen, showing different language options.

The first step was to switch it on, and to my joy, it made all the right noises and booted into a new operating system (albeit painfully slowly). But that joy suddenly turned to despair when I noticed a 20cm-long crack, right down the middle of the LCD screen. As I mentioned before, I always try and avoid cracked screens because they can't be repaired (only replaced) and the parts are very expensive.

Unless you can pick up the computer for an absolute bargain (or you already have a spare screen in your possession), they're just not worth buying.

The cracked screen

I quickly assessed the package and found out what had happened. The seller had placed the laptop and the charger into a very flimsy padded bag. At some stage while in transit, someone had parked a heavy weight on it and the charger was pressed into the lid of the laptop hard enough to crack the screen on the inside.

What was originally an easy fix had now become a monumental pain in the backside. I contacted the seller, who was very understanding and very apologetic. I took the package to my local Post Shop and asked what could be done. They kept it for a few days for assessment, but then decided that the level of padding was insufficient, and as such they would provide no compensation.

At this point, I told the seller and they refunded my money in full. I then told them that I would still be interested in buying the laptop but only if they dropped the price significantly. They agreed to the new price and I kept the laptop. I guess it all worked out reasonably well in the end; the seller still got some money for it and I still had a chance of repairing the computer. I just had to find a replacement screen at a reasonable price.

I decided to fix the "brains" of the

computer before I tracked down a replacement screen, so I headed to my workshop and began disassembling it. For any computer I dismantle, I always use the guides on the iFixit website (www.ifixit.com).

You just type in the model of the computer and if it's on file, a whole list of disassembly procedures are displayed, along with pretty pictures of all of the different screw types, sizes and the correct order for their removal. It sure saves me a lot of time.

Gone are the days of a few little Phillips head screws, with most modern laptops now being held together by a whole range of screw types, designed to stop us from unscrewing them. There are Phillips screws, Torx & Torx plus, hex, pentalobe, tri-lobe and split screws. Just when you think you have tools for all of them, you open up a computer and find a screw you've never seen before.

But I'm not easily discouraged, even though manufacturers seem to go out of their way to make repairs difficult. Some (famously including Apple) will refuse to work on a computer that has been repaired by someone else, so be prepared for failure if you're planning to try this for yourself. And never dismantle a computer that is under manufacturer's warranty as you will almost certainly void it.

Most of the computers I work on are three to five years old, which is enough time for any common faults to be well-documented. For example, I mentioned before that some of the MacBooks suffer from failed graphics chips. These chips are usually made by ATI or NVIDIA and are designed to be extremely powerful but seemingly at the expense of reliability.

Ball Grid Array (BGA) chips

The graphics chips run at constantly high temperatures and some of them fail after only a few years (and sometimes quicker). These are often difficult or even impossible to repair. Graphics chips are usually in Ball Grid Array (BGA) packages, which means they have a grid of tiny little solder balls on the underside of the chip housing. These line up with an array of pads on the motherboard.

...PUTTING THE MOTHERBOARD INTO THE OVEN FOR A BRIEF PERIOD

Heat is applied during assembly and the solder balls melt, attaching the chip to the board. For a large chip (like a graphics chip) which could easily have 500 or more contact points, replacing it is no easy task without specialised equipment.

And that's assuming you can find a suitable replacement. You may be forced to get one from another computer, which might fail in a week's time!

And don't be tempted by all of the videos on YouTube of people "repairing" faulty graphics chips by using a heat gun on the chip or by putting the motherboard into the oven for a brief period. These videos will usually feature a dead computer, which is then dismantled. Heat is applied to the graphics chip, then it is allowed to cool and Voila! It works again!

It sounds so easy. The reasoning provided for this procedure is that the solder balls under the chip have come away from the board and the heat is reflowing the solder, restoring contact.

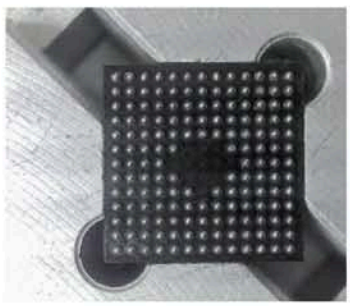
But in most situations, this is just not the case. Modern computers use lead-free solder, which has a melting point of about 190°C and in most of these demonstrations, these chips aren't getting hot enough for the solder to melt.

So why do they miraculously start working again? The answer is from inside the chip housing, not under it. The heat temporarily restores the tiny little contacts between the chip inside and the housing around it but it's often just a short-term fix. So when I see a computer for sale with a dead graphics chip, I leave it for someone else.

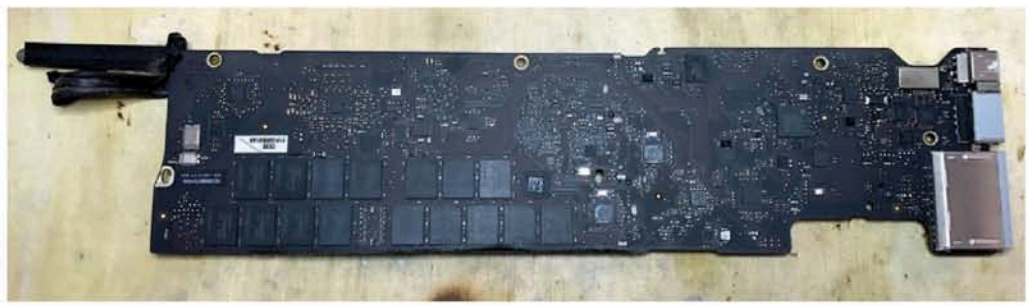
An important part of any fault diagnosis is having access to schematic diagrams and board-view files of the computer you're working on. While manufacturers normally hold these close to their chest, they do often get into circulation and a quick search on the internet may be fruitful.

Downloading these documents is an infringement of all sorts of manufacturer rules but it seems to be a fairly common practice and not policed. But you do so at your own risk.

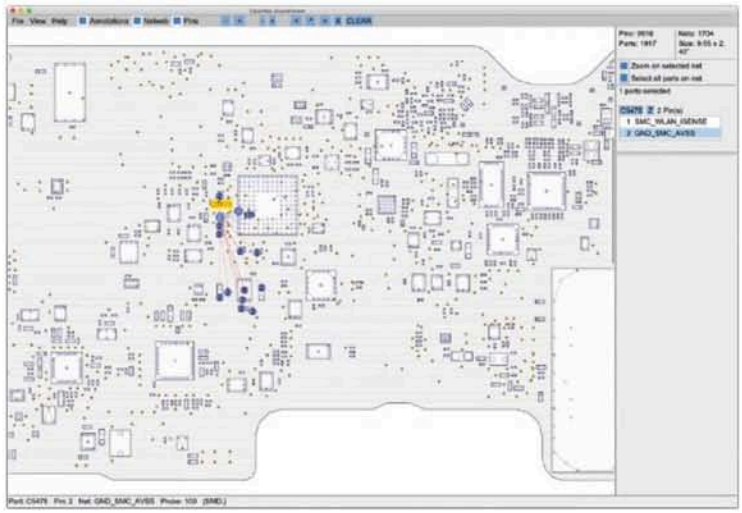
Board-view files are a CAD-style drawing of the motherboard, including every single component in its place, along with how each component is linked to every other component.

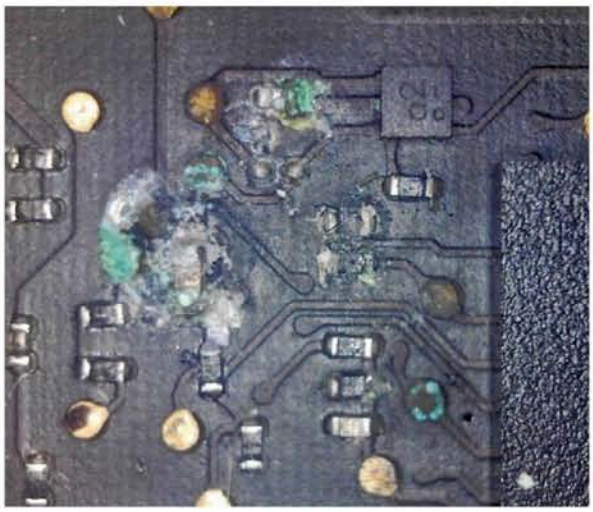


The BGA package underside, showing the solder balls.



The MacBook's motherboard before repair. You might be able to spot where the corrosion is on the board, from this photo.





Directly above is the board-view file for the motherboard, and to its right is a close-up of the selected area which shows the effects of the corrosion. Board-view files are like CAD drawings, but also include information on the placement of every component and how each is connected to the other.

They need to be viewed with a specific application, and there is a fantastic (and free) one called OpenBoardView, which is available for Windows, Mac and Linux.

Used in conjunction with a schematic diagram and multimeter, there's very little that can't be diagnosed, as long as you have a solid knowledge of electronics.

Initial diagnosis

So after opening my broken MacBook Air, I pulled out the motherboard for a closer inspection. I very methodically went over all of the components with a magnifying glass until I found... yuk!

A nice little nest of components, all showing corrosion from liquid damage. So the next step was to refer to my trusty board-view to find out what these parts do and if they were likely to be the cause of my problem.

Sure enough, they were very likely candidates. They all reside right next to the System Management Controller (SMC) which is responsible for controlling many of the physical parts of the machine, such as indicator lights, fans and (drum roll)... sensors – the most likely cause of my slow-running Mac. Some of the little resistors and capacitors were so badly corroded, they had actually cracked in half, so they needed to be replaced.

The next step was to remove and replace all of these damaged components. I didn't bother testing them all to see which ones were faulty, I just decided to replace all of them in the area of corrosion as it would be quicker.

I could have ordered these components from a supplier but generating a list would have been tedious and many of them are not available in small quantities. The logical solution is to locate a "donor board". These are motherboards from exactly the same computer model, made available cheaply on eBay, with many of the components still in place.

They have had all of the important chips removed (like the CPU, RAM and graphic chips) and have a couple of small holes drilled through the board (so that you'll never be able to repair them).

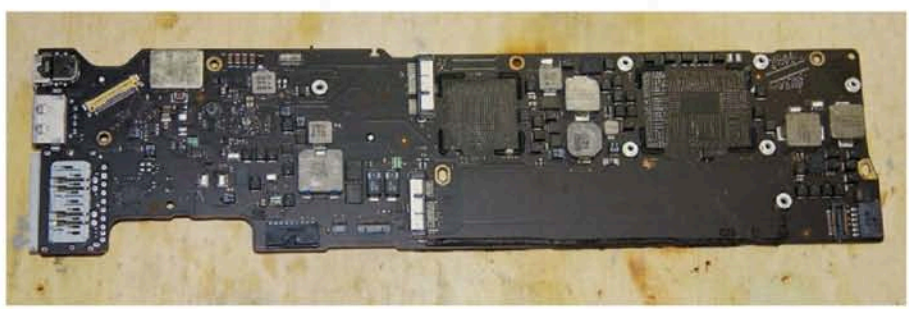
There's no guarantee that all of the parts on these boards are OK, but since they are quite cheap, it makes sense to buy a couple, in case one has damage in the same place as yours. My computer has an 820-3023 motherboard and I was able to buy a suitable donor board for just under $24, including delivery from China. So then it was just a matter of waiting for the donor board to arrive.

Just under two weeks later, I had my donor board. Thankfully, the parts I needed were all clean and intact, so I was ready to start the transplant. Some of these components are small, and I do mean small! Seven of the resistors I replaced were 0.6mm x 0.3mm. To provide some scale, an adult flea is around 2.5mm in length, so you really want to avoid sneezing while you're doing this work!

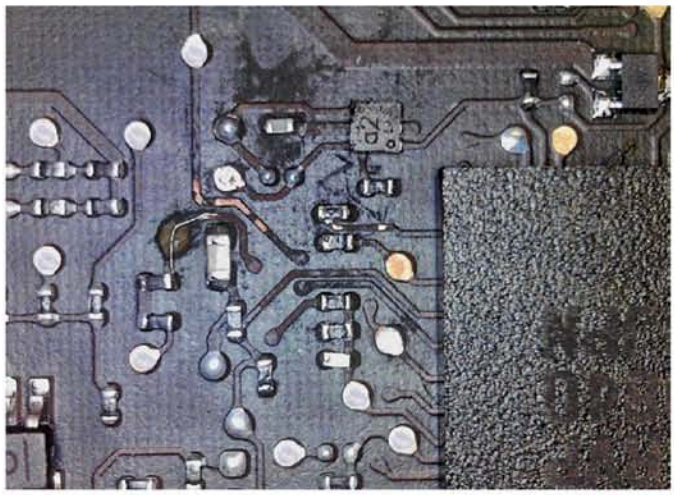
The donor board

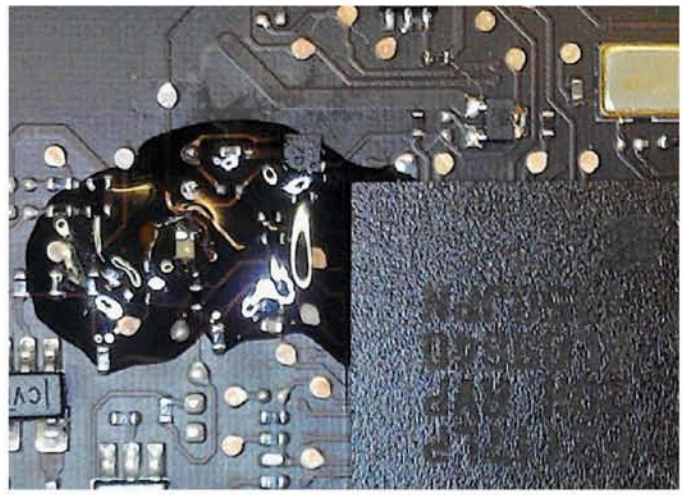
Before I go into details of the repair, here are some of the absolute essential tools needed to do these sorts of component-level repairs. The first is a good quality soldering iron. It needs to get hot enough to melt lead-free solder, and will need a very fine tip. I use a Hakko FX-951, but these are a bit pricey and a cheaper option would probably do the job just as well.

Just make sure you don't use one of those simple all-in-one irons with a great big fat tip for soldering household power cables. Use a good quality soldering station with a reasonably high output (mine is 70W).



The $24 donor board, as delivered straight from China. This board had most critical components stripped from their sockets, such as the CPU, GPU and RAM.





The components from the donor board, after having been transferred onto the original. One of the traces had corroded enough to split, so it had to be bridged using 0.1mm diameter wire. After cleaning and drying the board, this spot was covered with a small amount of silicone coating, as shown on the photo to the right.

The next essential item is a hot-air rework station. These are like a hot-air gun but with an adjustable temperature and airflow, and a selection of nozzles. Their main advantage is that you can heat a whole component, rather than just a single contact point and you can use them to solder or desolder components with hidden pads on the underside.

If you're trying to remove an IC with 30 or more pins, it's impossible to melt the solder all at once with a single soldering iron. A basic hot air rework station can be bought for well under $100.

You also need a good fume extractor. I choose to use leaded solder as I like working with the lower melting point but both lead and flux are toxic, so good ventilation is essential.

Another important item is solder wick. This is a finely-braided spool of copper wire that will draw in solder when heat is applied. It's usually impregnated with flux and since you only use a small amount at a time, it's quite cheap.

This helps you to remove solder from a PCB. I always clean the old solder off and apply new solder before putting new components in place.

You'll also need a good quality solder. I use a 0.35mm diameter 37% lead, 63% tin solder, which is specifically designed for surface mount work on PCBs.

And lastly (for now) you need a good quality no-clean flux. Just because your solder has flux in it already doesn't mean you should skimp on the flux. Flux helps the solder flow so a liberal amount of good quality flux is the difference between doing a good repair and ending up with a globby mess.

If in doubt, add more flux! I use Interflux gel, which is available in 10cc syringes from Mektronics Australia.

You'll also need a few smaller tools like tweezers and a good magnifying glass (or microscope) and plenty of light shining on your work area.

Doing the repairs

So the first step in my component transplant was to remove the old components from the corroded area of the board, which I did with my hot-air station and a fine pair of tweezers. I didn't need to keep any records of what I removed from where because I had my donor board with all of the components in their correct position to use as a reference.

Next, I used some solder wick and applied heat from my soldering iron to clean off all of the old solder. When using wick, make sure that you lift the iron and wick away from the board at the same time, while the solder is still liquid. Don't lift the iron first or the wick will stick to the pads and then you'll rip them off when you lift it.

It's important to be very gentle at this stage, because the pads are quite fragile. If the wick gets stuck, you'll need to apply more heat with your iron until it moves freely.

With the pads free of solder, I melted fresh solder onto each pad, ready for the new component to go in place. Next, I laid the two boards side-by-side and transferred the components one at a time, so that I didn't get them mixed up. I used my hot air station to heat the donor board, lift off a component with the tweezers, then place it in position on the original board.

I then gently adjusted the component's new position, relying on flux paste to hold it steady before applying heat with the hot air station to melt the solder. Surface tension then pulls the component into place.

This takes a lot of practice but if you do it correctly, you don't even need to touch the component when the solder is melting. As long as it's close to where it's supposed to be, it'll just naturally settle into the correct position, pulled by the melting solder and flux. This process would not be possible without adding a good quality flux.

All up, this process took me about half an hour, replacing eleven separate components: seven resistors, three capacitors and a small transistor. I put the computer back together to try it out and was extremely pleased when it started up, but disappointed to find that it was still running very slowly. So after all that work, I still hadn't fixed it.

So I pulled it all apart (again) and tried a few more tests. I was confident that the problem was still located in that area of corrosion, so I started looking at the traces, rather than the components.

I grabbed my multimeter, put it into resistance mode and carried out some continuity tests in that area. I found one spot where the signal clearly wasn't getting where it needed to go.

There was a point on the board that had been corroded so badly the trace had split apart. So now I had to find a way to create a bridge across this ugly mess.

Using a very sharp blade and a steady hand, I gently scraped off a bit of the protective solder mask layer on top of the trace, exposing the copper

Left: the ultrasonic cleaner used on the motherboard, after which it was placed in 100% alcohol and dried in an oven. Right: reassembling the MacBook with the now repaired motherboard.

beneath. I was then able to solder some 0.1mm diameter wire to bridge from one side of a resistor to the exposed copper, bypassing the corrosion.

This was incredibly fiddly, and didn't look too good, but it did the job, restoring continuity. So now with my fingers and toes firmly crossed, I put it back together for another test. Hooray! It was working at its normal speed; I had managed to fix it.

Even though I use a no-clean flux, I still like to get the board nice and clean before reassembly, so I dropped it into my ultrasonic cleaner. I use an inexpensive ultrasonic cleaner with a cleaning solution specifically made for PCBs.

eBay is probably the best place to look for an ultrasonic cleaner but just make sure you get one that's big enough for the stuff you need to clean and has a built-in heater. Definitely don't buy one of those really cheap jewellery cleaners. The cleaning solution I use is called "Electro" and can be purchased as a concentrate from Kleentek.

It's very counter-intuitive placing electronics into a liquid, but it's quite safe as long as the board is well dried before applying any power. After cleaning, I placed the board in a small bath of 100% isopropyl alcohol (which helps to displace any water).

I then heated the board in my kitchen oven for about 20 minutes, on a very low temperature (about 80°C) to dry it out. I could have just let the board dry by itself, but the oven speeds up the process.

This may sound scary but it's a process that I've done many times and it has never caused any damage.

With the board repaired, clean and dry, the last step was to put a small drop of silicone coating on the area I repaired to protect it. I then put everything back together. The most frustrating part of getting to this stage in the repair was knowing that if the screen hadn't been cracked in transit, I'd be done now!

The final steps

I began searching for a replacement screen assembly. I found plenty on eBay but they were going for about $500 each. That was going to put a nasty dent in my profit margin! Sometimes it's just a matter of looking at the right time, so I kept checking every few days to see if a more reasonably-priced display became available. After a week or two, I saw a second-hand display appear on eBay.

The description said "screen working perfectly... no dents... 30 day warranty" and it was selling for a lot less than any I had seen so far, so I grabbed it. A couple of days later, the new screen arrived, so I looked up the replacement procedure on iFixit and did the swap.

The new screen was in really good condition so after a quick clean, the whole thing came up looking a million bucks. It ended up costing me a bit more than I was expecting, but I still managed to make a small profit after selling it and I had fun too!

Conclusion

I learned many of these repair procedures by watching YouTube videos posted by New York laptop repairman Louis Rossmann. His language is a bit colourful at times, and he likes to rant, but he has literally hundreds of videos on repairing Mac laptops. It's an invaluable resource for anyone thinking about doing their own repairs.

SC

Almost as good as new; the laptop with a repaired motherboard and a replacement screen.

Building the 3-Way, Fully Adjustable Stereo Active Crossover for Loudspeakers

Part 2 – by John Clarke

Last month we described the circuitry and operation of our new 3-Way Adjustable Active Crossover for Loudspeakers. Now we continue with its construction – building the PCB, testing it, then putting it in its Acrylic case for a truly professional finish. It looks so good and works so well your friends won't believe you built it!

This Active Crossover has true hifi performance, as shown in the specification panel and accompanying plots. Harmonic distortion is well below 0.001% across most of the audible frequency range, rising to only about 0.0015% at 20kHz. The combined frequency response of the three outputs is almost completely flat from 20Hz to 20kHz.

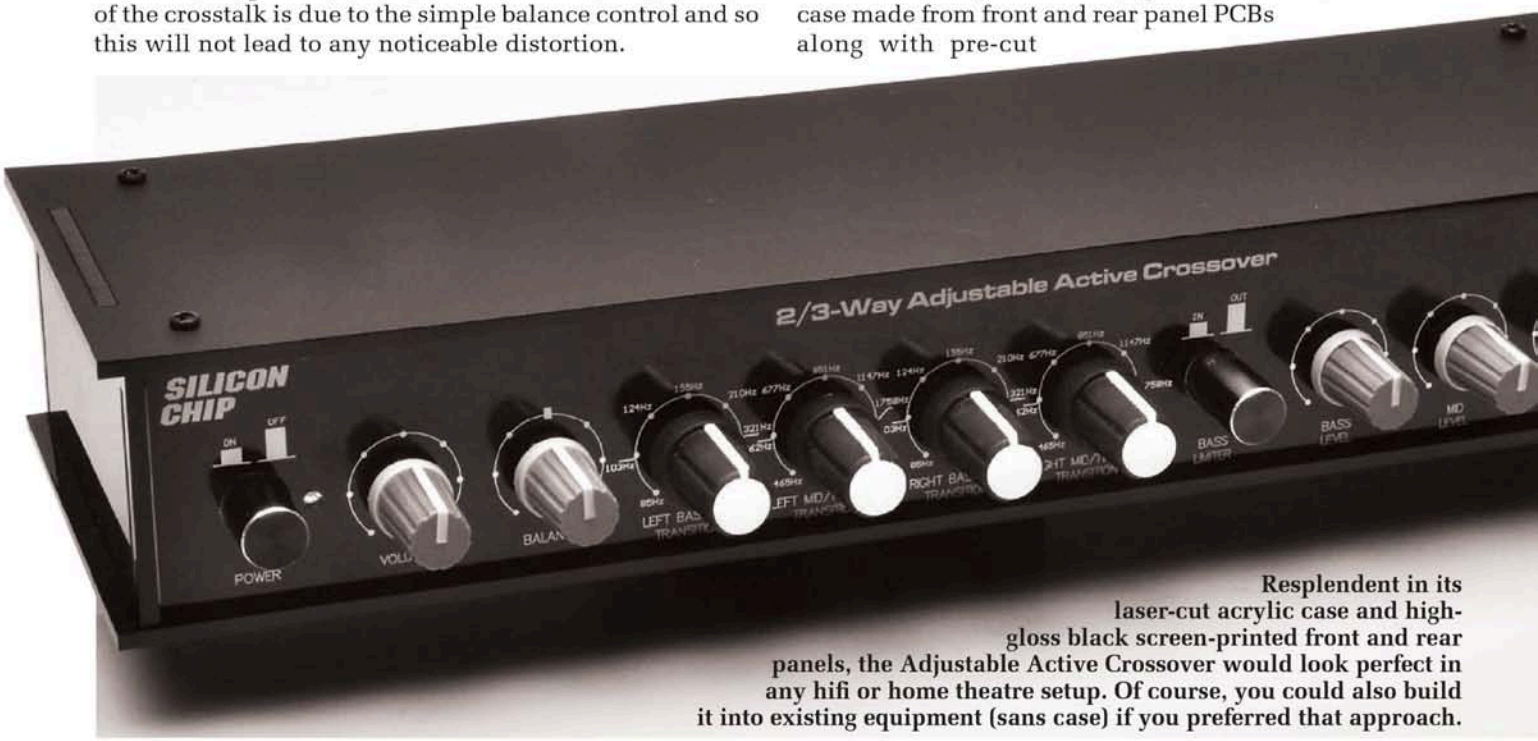
As you might expect, distortion is much higher when the bass limiter is actively limiting, at around 2% but this is much lower than the distortion you would otherwise experience with a woofer driven into clipping, which is what the limiter is designed to prevent.

Channel separation is around -50dB and note that most of the crosstalk is due to the simple balance control and so this will not lead to any noticeable distortion.

Tracking of the high-pass and low-pass filter pairs is very good, as you can see from the relevant frequency response plots (Figs.17 & 18). Overall, this Active Crossover will have insignificant effect on the signals passing through it and so will not "colour" or degrade the audio signals. Ultimately, that means that the sound quality you get depends entirely on the amplifiers and speakers used.

The project itself is constructed using a single PCB, coded 01108171 and measuring 284 x 77.5mm. It comprises a mixture of both through-hole and surface-mount components. Most are mounted on the top of the PCB but a few resistors and capacitors mount underneath.

The PCB and panels are designed to fit into a stand-alone case made from front and rear panel PCBs along with pre-cut



Resplendent in its laser-cut acrylic case and high-gloss black screen-printed front and rear panels, the Adjustable Active Crossover would look perfect in any hifi or home theatre setup. Of course, you could also build it into existing equipment (sans case) if you preferred that approach.

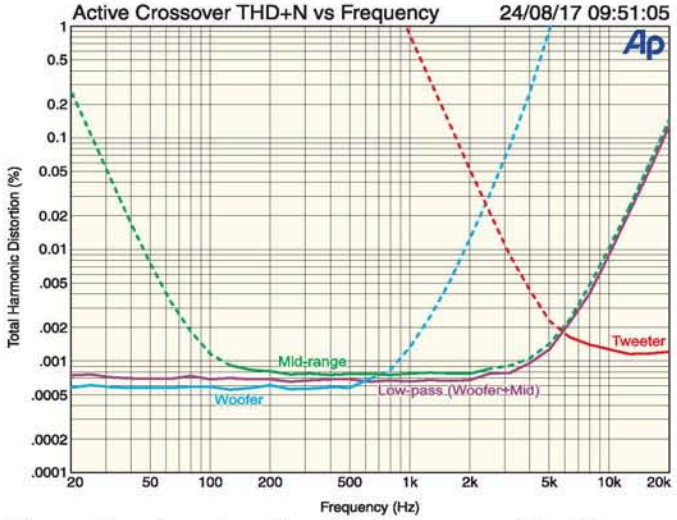


Fig.11: distortion plotted against frequency, with all four outputs measured independently. The dotted sections are where the amplitude of that output is dropping off, resulting in the distortion level appearing higher, due to diminishing signal-to-noise ratio. As you can see, at the frequencies where each output carries the majority of the signal, harmonic distortion is very low.

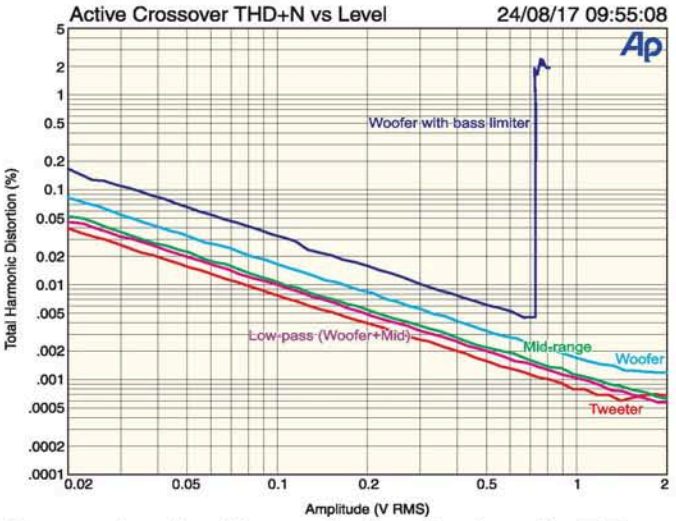


Fig.12: a plot of total harmonic distortion (actually THD + noise) against signal level for each output, demonstrating that almost all the distortion present is actually just noise. The dark blue curve demonstrates the operation of the bass limiter; the input signal was swept up to 2V with the unit set for unity gain, however, once the signal exceeds 0.72V RMS, the woofer output voltage barely rises further.

3mm black Acrylic panels. Alternatively, you could fit the PCB in a 1U rack case but then you would need to come up with your own mounting and panel arrangements.

And it's pounds to peanuts that it won't look as good as the Acrylic case!

Soldering SMDs

You will need a fine tipped soldering iron bit, 0.71mm diameter solder, a good light and a magnifying glass or spectacles to be able to solder the surface mount components in place.

Begin by mounting the surface mount ICs, all LM833 dual op amps. Each IC must be oriented correctly – note that the chamfered side is the pin 1-4 side of the IC.

The technique for soldering these in place is the same for all: locate the IC in position over its PCB pads and solder *one* corner pin. Check alignment and remelt the solder if the IC needs realignment.

When the IC is aligned correctly, solder the remaining pins. If you end up bridging adjacent pins, these can be cleared using solder wick.

Once all 25 ICs are soldered in, then align and solder the 100nF supply bypass capacitors (code 104) for each of these ICs. Check for a short circuit between each side of the 100nF capacitor after soldering each one as this can save a lot of time tracking down a short across the supplies later on.

The surface mount resistors can now be now be soldered in place. These are coded with a 4-digit number: the first three digits representing the value and the last digit representing the number of extra zeroes.

For example, a 1kΩ resistor (1000Ω) is labelled 1001: 100 plus one extra zero. For 100kΩ, (100,000Ω) the value is 100 with three extra zeroes. So it is labelled as 1003.

Install all the surface mount resistors on the top and bottom of the PCB. The remaining surface mount capacitors can now be fitted to the underside of the PCB.

Through-hole components

Once all the surface mount components are installed, the through-hole components can be mounted.

Start with the resistors first but don't throw out all the lead off-cuts. The two inductors (L1 and L2) are simply wire links which pass through ferrite beads. Here's where you use a couple of those resistor lead off-cuts!

The diodes also can be mounted, taking care with

Specifications

Measurement conditions:	2V RMS in, 1.5V out, 20Hz-20kHz bandwidth
Signal-to-noise ratio:	100dB+ *(100dB for tweeter, 105dB for midrange and 108dB for woofer)*
Frequency response, 20Hz-20kHz:	+0,-0.25dB *(see Fig.14)*
Total harmonic distortion plus noise:	<0.002%, 20Hz-20kHz *(see Fig.11)*
Distortion with bass limiter active:	~0.005% before limiting; ~2% while limiting *(see Fig.12)*
Output gain range:	zero (full attenuation) up to 3.8 times gain
Balance adjustment range:	±7.5dB
Bass/midrange crossover frequency (-6dB):	85-900Hz *(see Fig.18)*
Midrange/tweeter crossover frequency (-6dB):	465Hz-5kHz *(see Fig.17)*
Channel separation:	>46dB, 20Hz-20kHz *(see Fig.16)*
Input signal handling:	up to 2.6V RMS

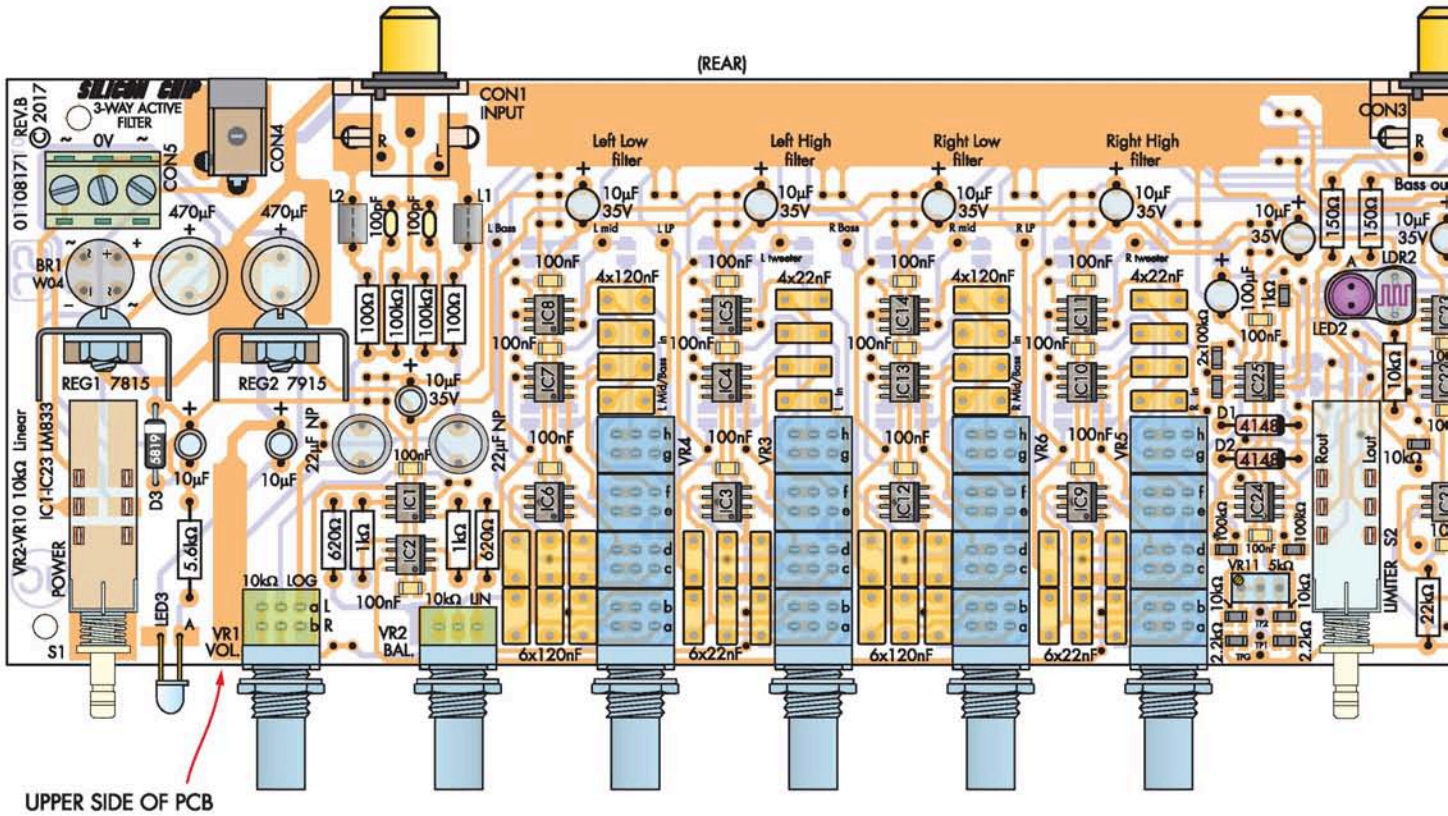
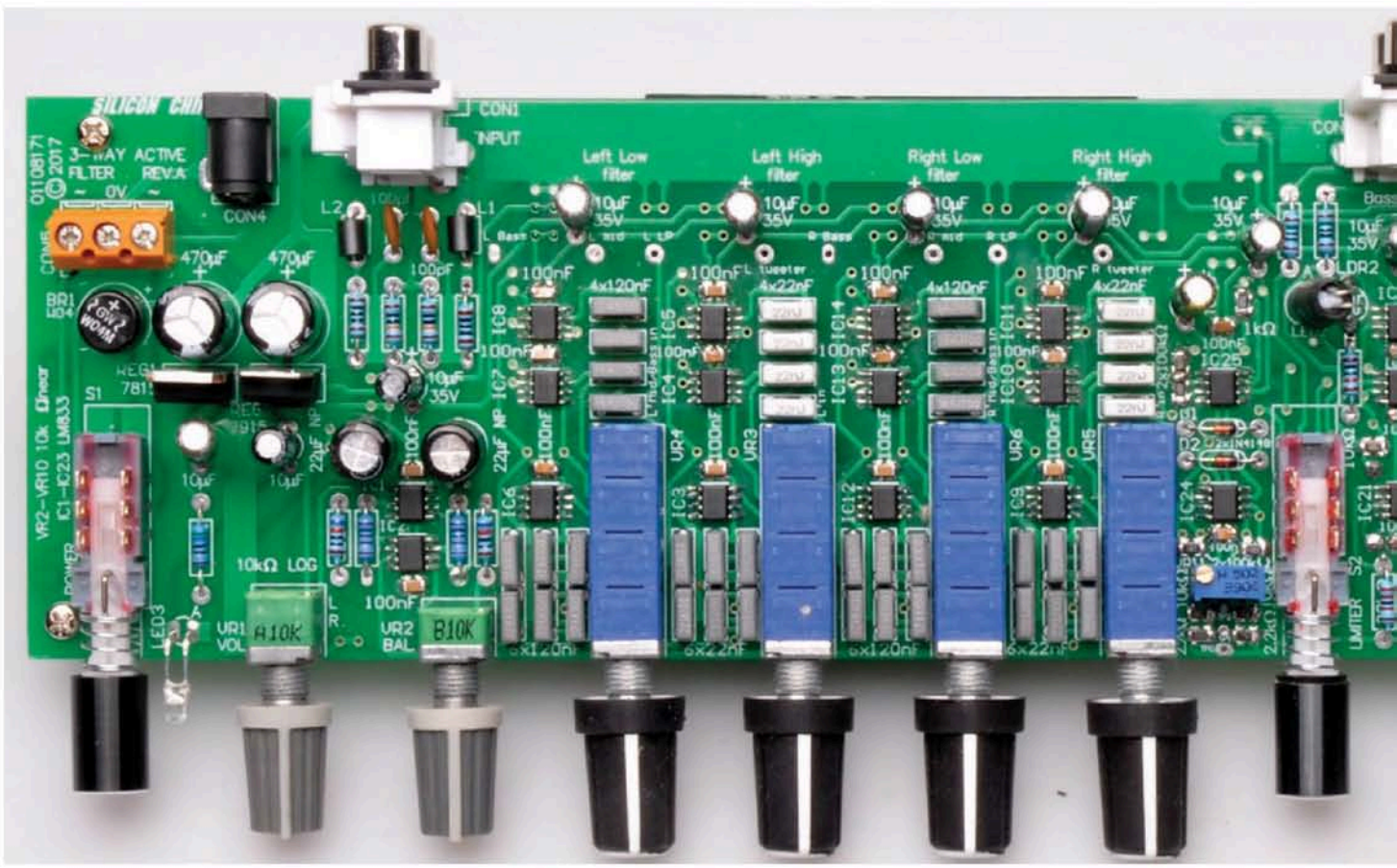
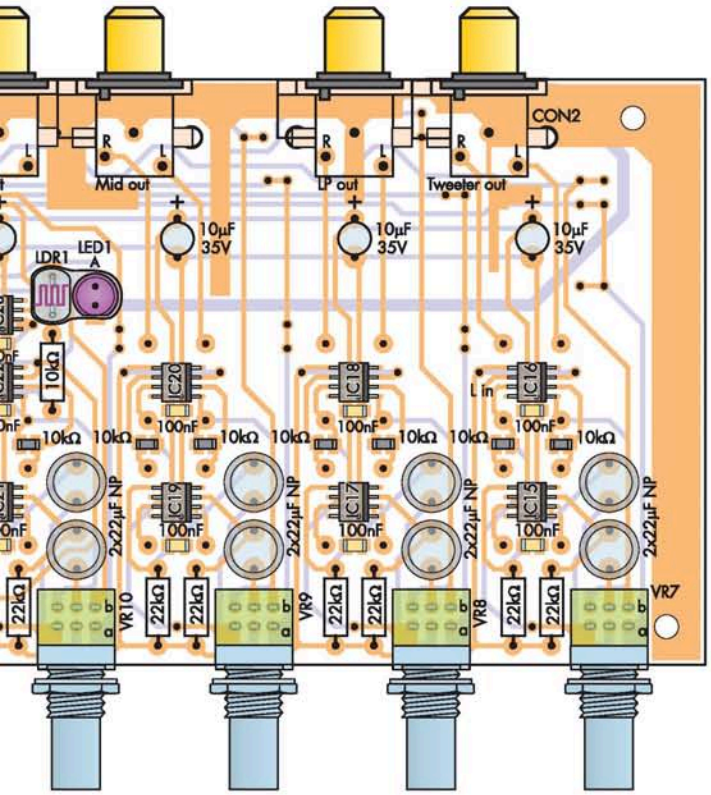
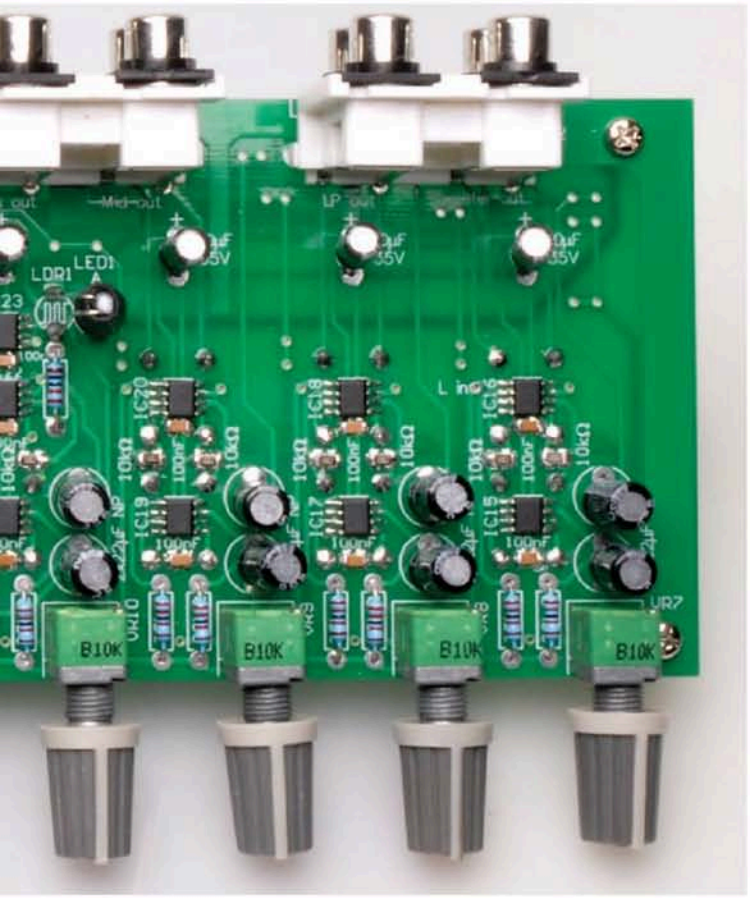


Fig.13: most of the components mount on the top side of the PCB, although there are quite a few SMD resistors and a few capacitors mounted on the underside (see overleaf). Use this component layout diagram along with the same-size photo below to assist you in construction. The full parts list was printed in part 1 of the 3-Way Active Crossover, published last month. The PCB is double sided, hence the number of apparently empty holes on the board which are "vias" going through to the opposite side.





Think you'll have difficulty with SMDs? You need a very fine-tipped iron, a good magnifying glass and a steady hand to solder them in. For all the tips, refer to the article "How to hand-solder very small surface-mount ICs," back in our October 2009 issue (siliconchip.com.au/Article/1590).



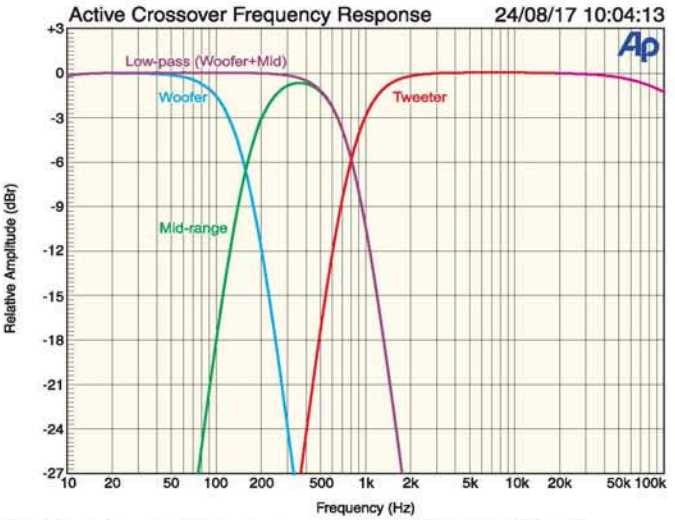


Fig.14: extended frequency response of each of the four outputs, showing that the -3dB points are well below 10Hz and above 100kHz respectively, making for a very flat summed response over the audible range (20Hz-20kHz). This demonstrates how the Tweeter and Low-pass outputs can be used as a two-way crossover, if necessary.

orientation (the striped end is the cathode [K]).

Now install the MKT polyester capacitors – there are 20 120nF and 20 22nF (these should be clearly labelled as such – see capacitor codes panel).

Electrolytic capacitors are mounted now. There are 35 in total – 25 are polarised and must be soldered in the right way around. The ten NP (Non Polarised) 22µF capacitors are not polarised.

Potentiometers

Check that the pins on the potentiometers are all straight before insertion – if necessary, straighten them using flat nose pliers. Double check that each pin has entered its hole before soldering in place.

The 8-ganged pots are best inserted by placing in the back row of leads first (ie angle the potentiometer slightly) and then progressively insert the remaining pins as the pot is lowered onto the PCB.

Be careful with VR1, VR2 and VR7-VR10 as these have the same value (10kΩ) but VR1 is a log type (marked "A"), while the remaining are linear (marked "B").

VR11, the bass limiter threshold preset, is mounted with the screw adjustment to the left.

Power supply

Next to go in are the power supply components. All of these are polarised so be careful with orientation.

First is the bridge rectifier, followed by the four filter capacitors (two 470µF and two 10µF), the Schottky diode and the two 15V regulators (again, note that they are different!). Both regulators should have their heatsinks attached via M3 screws and nuts before soldering in. Seat the regulators as far down on the PCB as their heatsinks will allow.

LED1 needs to mount with the correct orientation (longer lead is the anode) and to allow it to poke through the front panel, is bent over at 90°, at 6mm back from the rear of the LED body.

Provision is made for a single 16VAC supply via CON4 or a 15V-0-15VAC supply via CON5. You will only need

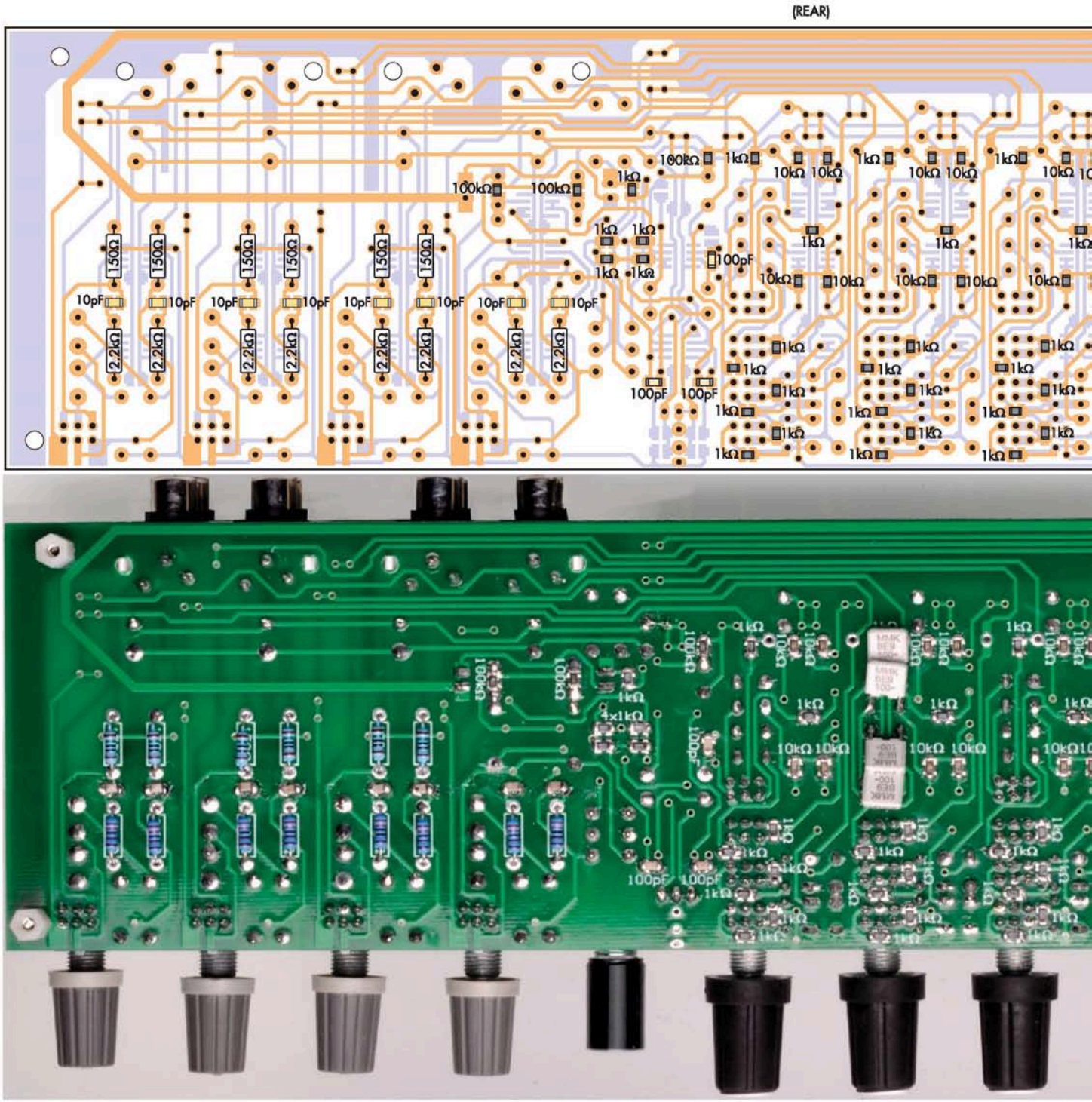


Fig.15: the component overlay and matching photo for the reverse (or under) side of the PCB shows the large number of SMD resistors and capacitors to be placed. The eight 100nF capacitors in the photo are only there because at the time, we'd run out of 120nF MKT capacitors (normally mounted on the top side of the board!) Similarly, the diode shown tacked across the board in this prototype has been replaced with one mounted on the top side in the final version of the PCB.

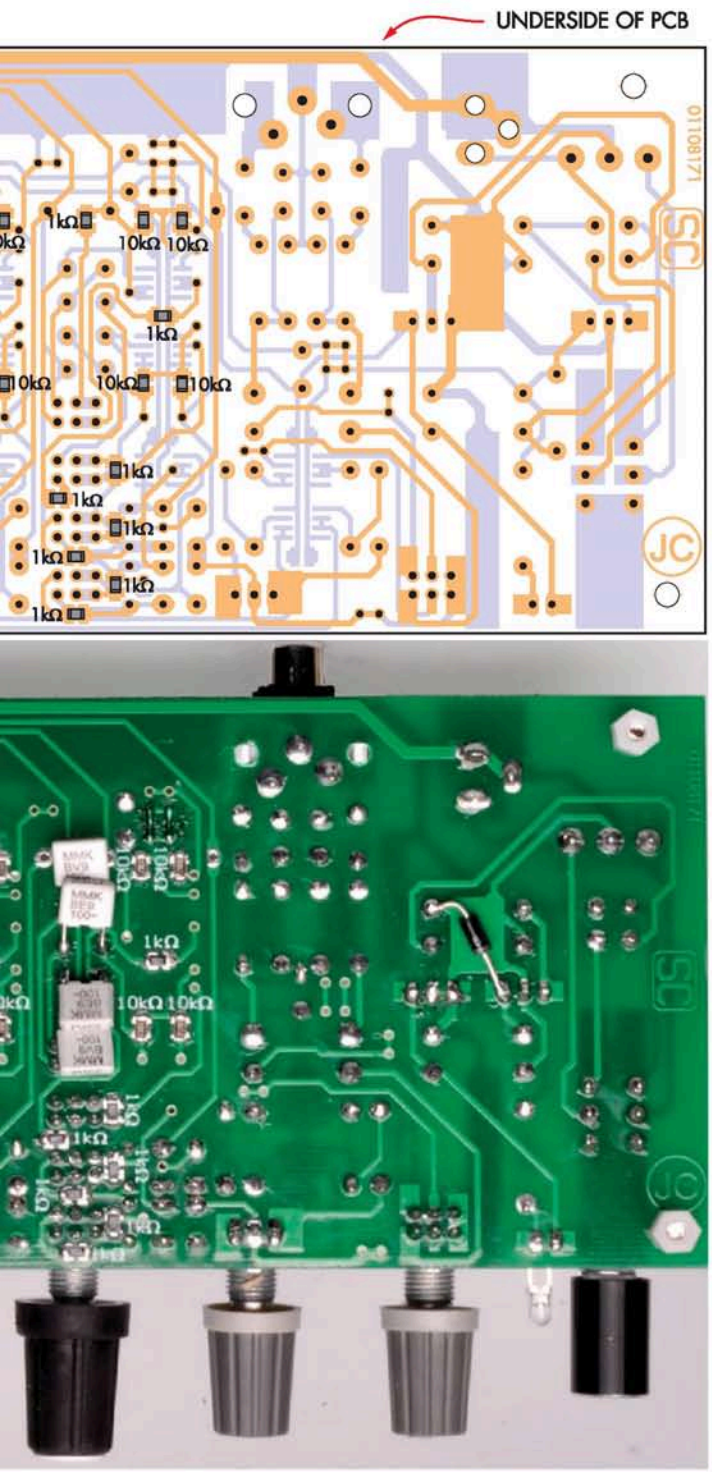
one of these. If using CON5 (a 3-way screw terminal) it is mounted with the opening toward the PCB edge.

LDR and LED pairs

LDR1/LED1 and LDR2/LED2 need to be made into two separate lightproof assemblies. Each assembly allows light from the LED to directly shine onto the face of an LDR.

We used 6mm diameter black heatshrink tubing cut to 25mm in length to cover and secure the LED and LDR together and with a small bead of Blu-Tack (or similar) at the rear of each LED and LDR to prevent light entering from outside of the tubing. Orient the leads of the LED to the same plane as the LDR before shrinking the tubing with a hot air gun.

When installing onto the PCB, ensure that the LEDs are oriented correctly with the longer lead (the anode) inserted into the "A" marked position. We inserted the LED directly onto the PCB with the LDR leads bent over to insert into



the LDR allocated holes. The LEDs are polarised but the LDR leads can be oriented either way in the PCB.

See the photo at right for more detail.

That should have completed construction of the PCB but before putting it in its case, we need to test it and set up VR11.

Initial testing

Apply power (either 16VAC via CON4 or 15-0-15VAC via CON5) to test for voltage at the op amps. Switch on S1 and the power LED should light. Now measure voltage between pin 4 and pin 8 of one of the op amps. This should be close to 30V (ie, +15 to -15V).

If this is not correct, switch off power and check construction for correct parts placement or for shorts on the power supply rails.

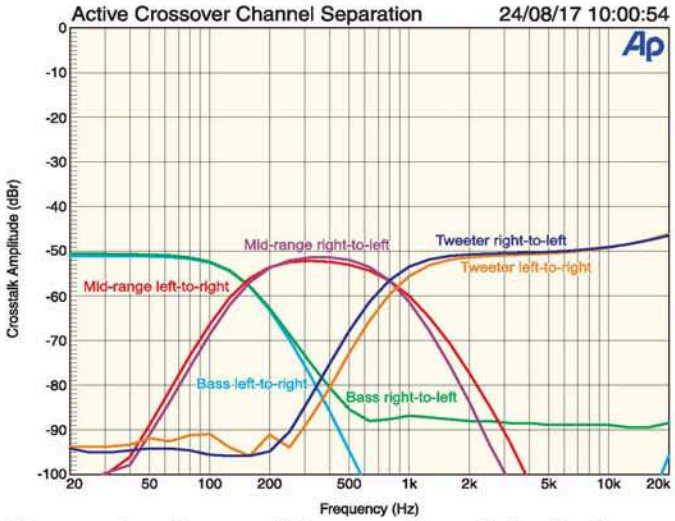


Fig.16: a plot of cross-talk between channels for the three primary outputs. As you would expect, cross-talk is highest within the frequency range that the output retains. Most of the cross-talk is due to the shared signal paths in the balance circuitry, with only a slight hint of capacitive cross-talk at higher frequencies (this effect is reduced at higher mid-range/tweeter crossover frequency settings).

Setting it up

The input sockets can be connected either to the output of a preamplifier or directly to a line-level signal source such as a CD/DVD/Blu-ray player, MP3 player or mobile phone (thanks to the onboard volume control).

For driving a pair of 3-way loudspeakers, the woofer, mid-range and tweeter outputs should be connected to three stereo amplifiers, ie, one to power the woofers, one the mid-range drivers and one the tweeters.

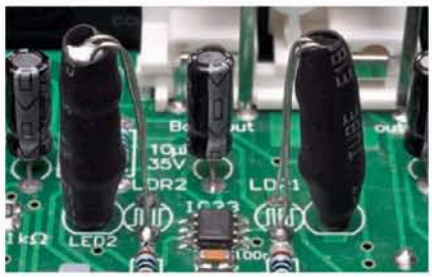
It's common practice to use lower power amplifiers for the mid-range drivers than woofers, and again for the tweeters than the mid-range drivers.

Note though that some (fairly unusual) program material may overload the amplifiers in such a configuration. Rock/pop music is normally safe in this sort of configuration as it is usually quite bass-heavy and so will overload the (larger) woofer amplifier first.

You will then need to determine the correct crossover frequencies, based on the specifications of your drivers and the cabinets they are mounted in and adjust the unit accordingly.

Making the adjustments

The easiest way to set the crossover frequencies is with an adjustable signal generator and AC millivoltmeter. You



This close-up shows the two LED/LDR assemblies, arranged so the light from the LEDs shine directly into their LDRs. Black heat-shrink makes them lightproof.

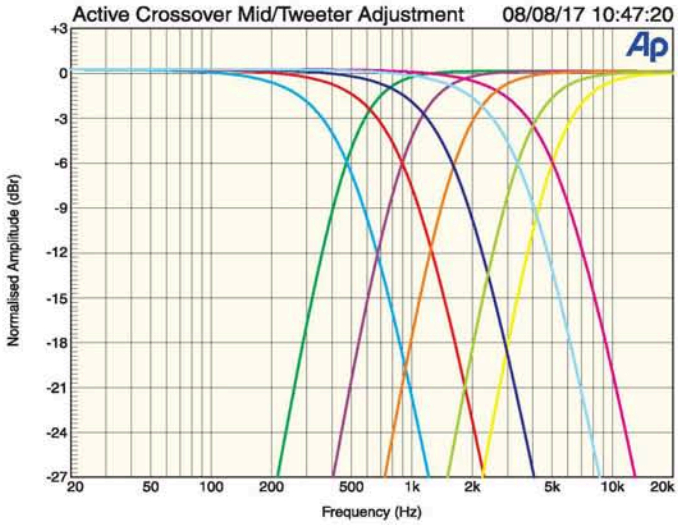


Fig.17: simultaneous frequency response plots of the woofer+mid and tweeter outputs with five different crossover frequency settings. This demonstrates the adjustment range and filter tracking and also shows how the unit can be used as a two-way crossover. In three-way mode, the effect is the same but the mid-range response will be hump-shaped, rather than extending all the way down to 20Hz.

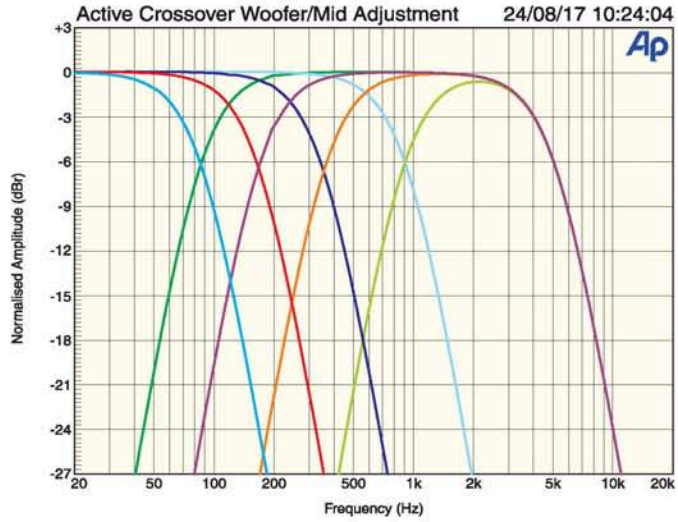


Fig.18: simultaneous frequency response plots of the woofer and mid-range outputs with four different crossover frequency settings. This demonstrates the adjustment range and filter tracking. With the woofer/mid crossover set to 900Hz, this is close enough to the mid/tweeter crossover frequency that the peak output level is below 0dB. Otherwise, it would produce a peak in the summed frequency response.

will need a signal generator that has a stable amplitude across a wide range of frequencies (eg, 30Hz to 10kHz or wider, if possible) and an AC millivoltmeter which can measure up to about 1V RMS and is accurate across the same frequency range.

If you don't have such tools, you could purchase them or alternatively, build our Digital Audio Millivoltmeter project from March 2009 (www.siliconchip.com.au/Article/1372) and/or the Touchscreen DDS Signal Generator from the April 2017 issue (www.siliconchip.com.au/Article/10616).

Set the signal generator output to 30Hz and around 1V RMS and set all four level controls on the Active Crossover to maximum.

Hook up the signal generator to the inputs and the millivoltmeter across the centre pins of the two woofer outputs (we're assuming it has a battery or floating mains supply, ie, its ground is not earthed). Adjust the balance control until the millivoltmeter reads zero, indicating that the channels are correctly balanced.

Then connect the millivoltmeter normally to measure the left channel woofer output level. Adjust the volume control to get a reading of 1V RMS.

Next, set your signal generator frequency to be your desired woofer/mid-range crossover frequency and then adjust the left channel lower crossover frequency potentiometer until you get a reading of 500mV RMS. This is 1V RMS minus 6dB.

Then connect your millivoltmeter to the right channel woofer output and adjust the right channel lower crossover frequency to get the same result.

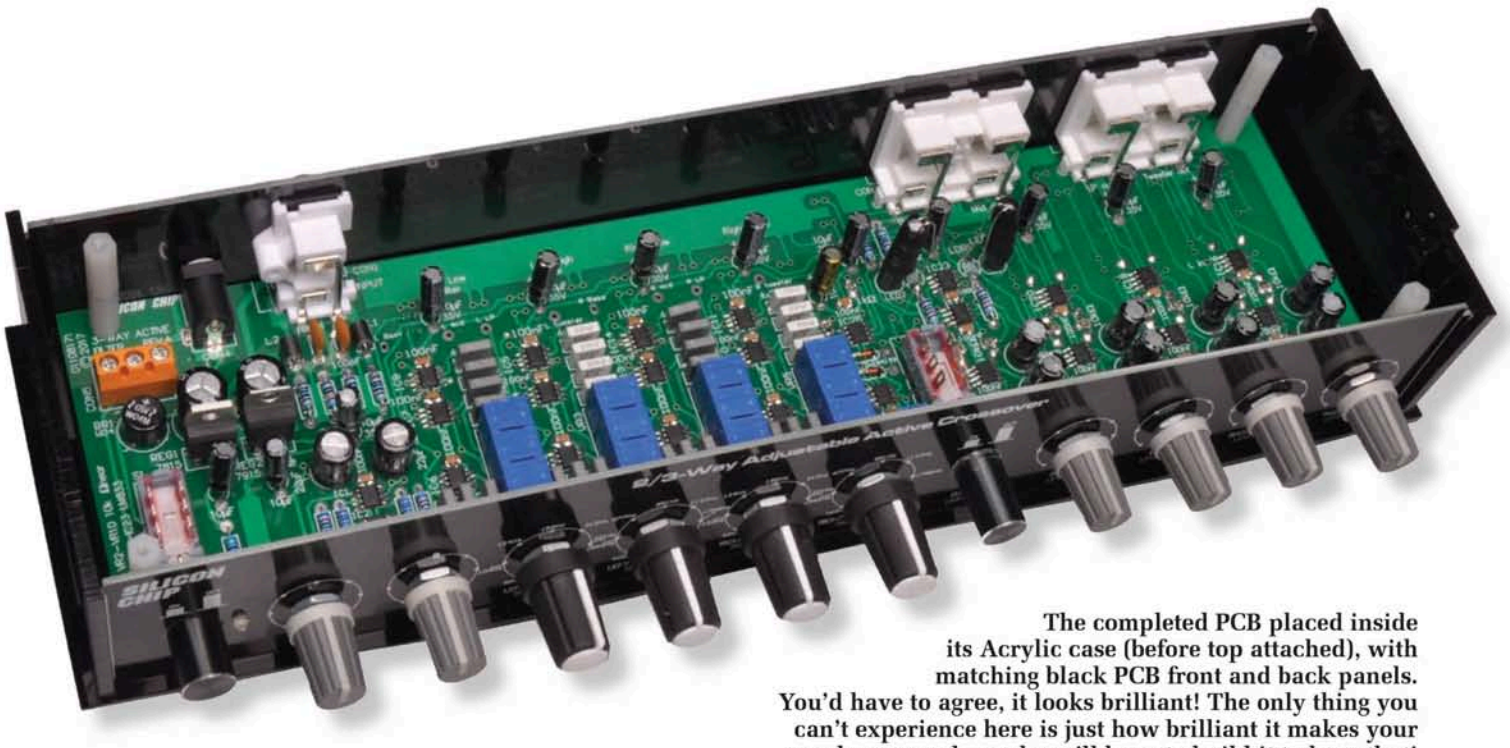
The procedure for adjusting the upper crossover threshold is the same except that you start with a 10kHz signal and adjust the tweeter output

Small Capacitor Codes

	No.	Value	SMD	EIA	IEC
❑	20	120nF MKT		124	120n
❑	25	100nF (1206)	A5		
❑	20	22nF MKT		223	22n
❑	11	100pF (1206)	A2		
❑	2	100pF ceramic		101	100p

Resistor Through-Hole Colour Codes and SMD Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	100kΩ	brown black yellow brown	brown black black orange brown
❑	7	100kΩ	1206 SMD – code 104 (or 1003 in E24)	
❑	8	22kΩ	red red orange brown	red red black red brown
❑	2	10kΩ	brown black orange brown	brown black black red brown
❑	26	10kΩ	1206 SMD – code 103 (or 1002 in E24)	
❑	1	5.6kΩ	green blue red brown	green blue black brown brown
❑	8	2.2kΩ	red red red brown	red red black brown brown
❑	2	2.2kΩ	1206 SMD – code 222 (or 2201 in E24)	
❑	2	1kΩ	brown black red brown	brown black black brown brown
❑	37	1kΩ	1206 SMD – code 102 (or 1001 in E24)	
❑	2	620Ω	blue red brown brown	blue red black black brown
❑	8	150Ω	brown green brown brown	brown green black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown



The completed PCB placed inside its Acrylic case (before top attached), with matching black PCB front and back panels. You'd have to agree, it looks brilliant! The only thing you can't experience here is just how brilliant it makes your speakers sound – and you'll have to build it to hear that!

level control to get 1V RMS, then set the signal frequency to your desired crossover frequency and adjust both upper crossover frequency adjustment pots until you read 500mV at both tweeter outputs.

You can then set the generator to a frequency in the middle of your mid-range band and adjust the midrange level output to get a reading of 1V RMS.

Adjusting the output level for each pair of drivers

At this point, you have set the crossover frequencies and the output amplitudes are all set to be identical, giving you a flat summed response. However, chances are your drivers do not have identical sensitivities.

Also, your individual amplifiers may not have the same gain. So you will need to change the relative levels of the outputs so that the drivers are producing identical sound levels at the crossover point(s).

Start by determining the sensitivities of each driver. These are normally specified by the manufacturer or supplier and are in units of decibels (sound pressure level) per watt at one metre (dB[SPL]/W @ 1m).

In order to better explain the procedure, we'll use a hypothetical example of a three-way speaker system with drivers as shown in Table 1.

In this example, each driver has a different sensitivity figure and the woofer's impedance is different from the other two. The stereo amplifiers used to drive each pair also have different gains, as indicated.

Impedance has an effect because this determines the signal amplitude required to deliver one watt to the driver. To determine the required voltage, take the square root of the impedance. So for a 4-ohm driver, you need 2V RMS ($P = V^2 \div R$); for an 8-ohm driver, you need 2.828V RMS; and for a 6-ohm driver, you need 2.45V RMS.

Now divide the required signal level by the amplifier gain to determine the signal that you need to feed into the amplifier to get 1W out of the driver. If you only have a dB gain figure, use the formula 10^(dB÷20) to determine the linear gain factor.

If your amplifier has a volume knob, the gain will depend on its setting; unless you plan on running it at maximum gain (and you already know what that is), you will have to feed a signal into the amplifier, measure the input and output amplitude and divide the output voltage by the input to determine the gain.

We suggest you do this before wiring up the outputs since otherwise it may be very loud and depending on the signal level you inject, you could damage the driver. This may result in a slightly higher reading (due to the outputs being unloaded) but the difference is unlikely to be significant.

So, in the case of our tweeter, we can compute the required amplifier input signal for 1W as 282.8mV RMS (2.828V÷10). For the mid-range driver, it's 188.6mV (2.828V ÷15) and for the woofer it's 100mV RMS (2V÷20).

Now we convert these figures to dB(V) using the formula $dB(V) = 20\log_{10}(VRMS)$. If your calculator doesn't have a base-10 log function, you can take the base-e (natural) log and then divide by the natural log of 10, ie, $\log_{10}(x) = \log_e(x) \div \log_e(10)$.

This gives us figures of -11dBV for the tweeter, -14.5dBV for the mid-range driver and -20dBV for the woofer. Subtract the sensitivity figures from these values to get the required signal level to produce 1dB(SPL). These are shown in Table 1. This reveals that the mid-range driver requires the highest signal level, followed by the tweeter and then the woofer.

	Sensitivity	Impedance	Amplifier gain	Input level for 1dB(SPL)
Tweeter	96dB/W@1m	8Ω	10x (20dB)	-107dBV
Mid-range	89dB/W@1m	8Ω	15x (30dB)	-103.5dBV
Woofer	92dB/W@1m	4Ω	20x (40dB)	-112dBV

Table 1 – example of speaker system level adjustment

The first step to make the adjustments then is to set the output level for the mid-range driver to its maximum setting, feed a reference signal into the Active Crossover in the middle of the mid-range driver's frequency band (ie, between the two crossover points) and then adjust the input volume control until we get a reference level of 1V RMS at the mid-range output sockets.

Based on the figures we've just computed, we can determine that the tweeter output should be 3.5dB lower than this reference level.

Using the formula 10^(dBV÷20) we can determine that the tweeter output voltage needs to be adjusted to 10^(-3.5÷20) = 0.668V or 668mV. Use a similar procedure, injecting a signal of the same amplitude as before but in the tweeter's frequency range (say, 10kHz) and then adjust the tweeter output to this level.

Similarly, we can compute the woofer output for the same amplitude input signal, at an appropriate frequency, should give an output of 10^(-8.5÷20) = 376mV RMS (-8.5 = [-112] - [-103.5]).

If you're using the unit as a two-way crossover, the procedure is essentially the same except that you set either the Tweeter or Low-pass (Woofer+Mid) output to 1V RMS and then adjust the other once you've computed the difference in level required.

Tweaking it

In a perfect world, the above procedure should give you a nearly flat response from your loudspeakers. However, there are a number of factors which can throw a spanner in the works.

For example, the fact that the drivers you purchase may not have exactly the sensitivity or frequency response the manufacturer specified. They may not even be identical to each other!

Then you also have effects of the enclosure on the performance of the drivers, the fact that their impedance will not be exactly the nominal value and will vary with frequency and so on.

All this means that that the setting you made above will only be approximately correct. It may well be good enough, but unless you make further measurements and do tweaking, you won't know if it can be improved upon.

The most scientific way to finish adjusting the Active Crossover to give the best results is using a device which can actually measure the frequency response of the loudspeaker, allowing you to calculate (or at least estimate) any further adjustments which need to be made to improve it.

You don't need particularly expensive equipment to do this. See our article titled "*How to do your own loudspeaker measurements*" in the December 2011 issue (**www.siliconchip.com.au/Article/1248**), which describes how to use the low-cost Champ and Prechamp amplifier boards, with an electret microphone, a PC and a few other bits and pieces to measure loudspeaker frequency response.

Assuming you go to the trouble of building such a rig, once you have measured the response, it's then just a matter of determining whether you need to slightly increase or decrease the level to one driver in order to even out the speaker's overall response.

If you do, you will normally notice a "shelving" effect in the response curve. You can then re-measure to verify that your change is an improvement.

As we said earlier, various factors such as driver variances and enclosure design can also affect a driver's frequency response and thus you may find that there are dips or peaks near the crossover frequencies.

If so, this suggests that you may be able to flatten the response by adjusting the crossover frequency itself. You will need to make small adjustments and re-measure the loudspeaker to verify that your change led to an improvement (if not, reverse it).

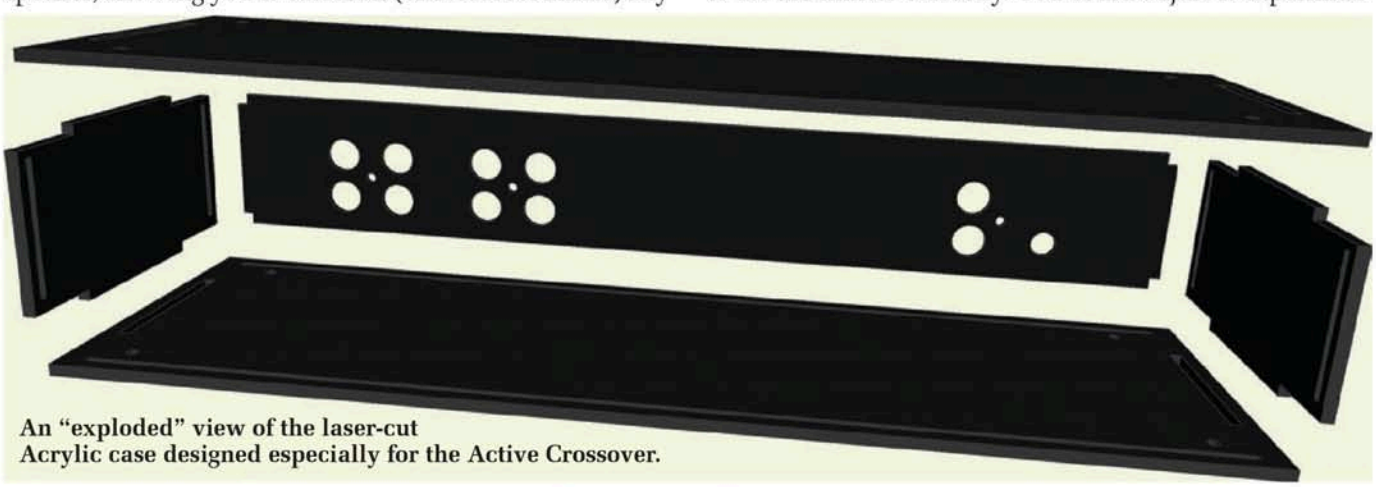
This is an iterative process and you may need to make a number of adjustments before you are happy with the overall response.

If you don't have the equipment to do this and you have well-calibrated ears and a good variety of source material, which you are familiar with (ideally, having listened to it multiple times on speakers or headphones with a flat response), you might trust yourself to tweak the crossover "by ear". There is no guarantee that you will get the best result with this method, though!

Limiter adjustment

The signal level at which the bass limiter becomes active (when switched on via S3) can be adjusted using trimpot VR11.

Typically, you would set the limiter to restrict the signal level so that the amplifier/woofer combination you are using does not run into clipping. The signal level at which clipping occurs depends on the amplifier power rating, its gain, the woofer power rating and its impedance. So you will need to calculate the signal level at which clipping will occur to set the limiter correctly. You could adjust it experimen-



An "exploded" view of the laser-cut Acrylic case designed especially for the Active Crossover.

tally, however you risk causing damage using that method.

Briefly, take the lower of the two power ratings (amplifier or woofer, taking into account the woofer's nominal impedance) and then calculate the RMS voltage required to be delivered to the woofer's impedance to achieve that power level using the formula $V = \sqrt{P \times R}$. Then divide this by the amplifier's gain to determine the maximum signal level at the amplifier's input. You can then multiply this RMS voltage by 1.414 to calculate the maximum peak signal voltage before clipping occurs.

The limiter level can be monitored between TPG and TP1 for the positive peak level and TPG and TP2 for the negative level. You should get a similar reading in both cases (with opposite polarity). Adjust VR11 until the voltages at TP1 and TP2 are just below the peak voltage level you computed above.

Acrylic case

The case is formed from four pieces which slot together, forming the top, bottom and ends. The front and back of the case are high-gloss, screen printed PCBs with drilled holes for the controls, connectors and LED.

The whole lot is held together with eight screws and twelve tapped spacers, along with tabs and slots joining the panels to each other.

The first step is to loosely fit the front and rear panels to the main PCB. The rear panel slips on over the 10 RCA connectors and is held in place with three short black 4GA self-tapping screws which go into the middle of the two 4-way RCA sockets and to the side of the 2-way RCA socket.

Before fitting the front panel, you will need to remove the nuts and washers from all the potentiometers. It's then just a matter of slipping the panel over the pot shafts and loosely re-attaching the washers and nuts while guiding LED1 into its hole.

Now remove the protective film from the base panel. This is the largest acrylic panel, with two extra slots compared to the top. Do this carefully since the two long slots are near the edges of the panel, making it relatively weak – don't hold it by these edges or press on them.

You can orientate the acrylic panels so that the outside (visible) faces are either matte or gloss black; we prefer matte, since it gives better resistance to fingerprints and hides scratches.

Feed the four 32mm machine screws up through the bottom and screw a 9mm tapped Nylon spacer onto each shaft until the screw is held firmly in place.

Now remove the protective coating from the two side panels and push the onto the sides of the front and rear panels, so that the tabs in those panels go through the slots on the side panels.

You can then lower the PCB onto the bottom panel, lining up the screws with its mounting holes. Screw four 15mm M3 spacers fully onto the screw shafts to hold the PCB in place, then screw the other four 15mm spacers on top.

Now you can remove the protective coating from the top panel and lower it into place. You may need to cajole the front and rear panels to fit into the slots.

Use four black M3 x 8mm machine screws to attach it to the top of the four spacers, then tighten up all the potentiometer nuts and push the knobs onto the pot shafts. Stick on some rubber feet and the case is complete. SC

SAD HAPPY

Because you can't find that difficult-to-get special project part at your normal parts supplier. . .
Or perhaps they've discontinued the kit you really want to build. . .

To discover that the elusive bit that you want is stocked in the **SILICON CHIP ONLINE SHOP!** There's a great range of semis, other active and passive components, BIG LEDs, PCBs, SMDs, cases, panels, programmed micros AND MUCH MORE that you may find hard to get elsewhere!

If it's been published in a recent SILICON CHIP project and your normal supplier doesn't stock it, chances are the SILICON CHIP ONLINE SHOP does!

YES! We also stock most SILICON CHIP project PCBs from 2010 and even earlier!

Don't forget: SILICON CHIP Subscribers qualify for a 10% discount on all shop items!*

Log on now: www.siliconchip.com.au/shop

* Excluding subscriptions

Higher power, loads more features . . .

Deluxe Touch-screen eFuse

by Nicholas Vinen

Part 3: final assembly and operation

Having built the PCB assembly for our Deluxe Touchscreen eFuse and performed some basic tests, we're going to conclude the story by attaching the six chunky binding posts, attaching the classy matte black laser-cut lid and fitting it into its case. We'll also show some screen grabs and explain how to use the unit and operate its touchscreen interface.

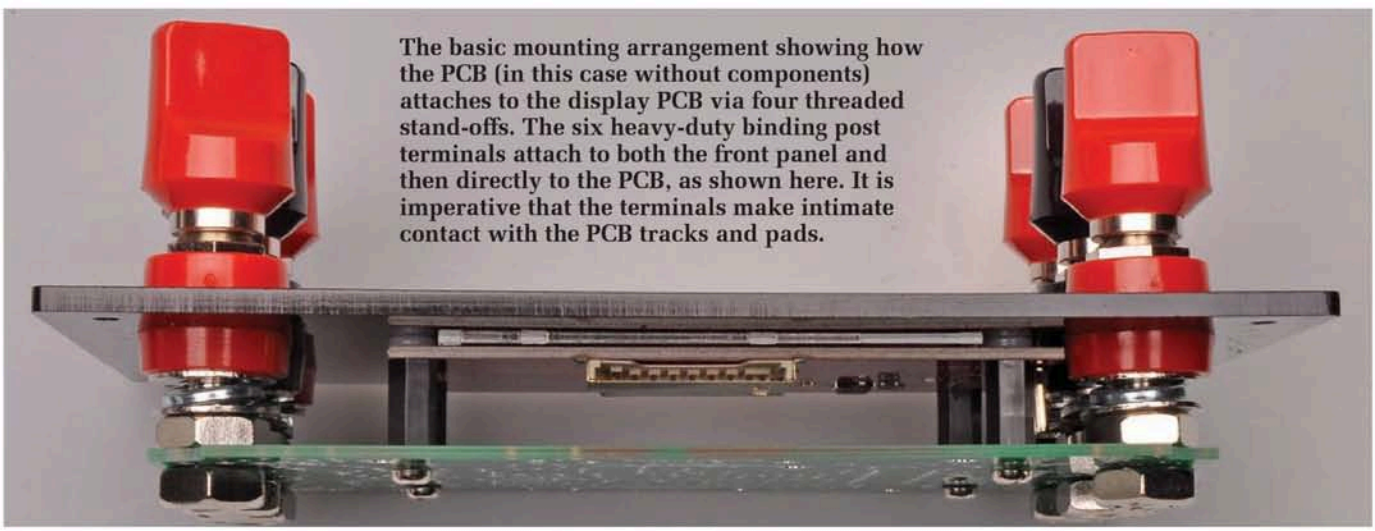
At the end of part two in the August issue, we left off with a fully assembled and tested unit needing only to be put into its case. The photo below shows how the finished assembly is mounted to the lid. This shows the terminals attached to a bare PCB so that you can clearly see the mounting arrangement.

Start by removing the washers, nuts and lower half of the plastic shell from each binding post. Feed each binding post through from the top of the lid, with the four red posts in the corners and two black posts in between.

Place the other half of the plastic shell on the underside of the lid and rotate the top and bottom halves until they slip into the locking slots in the lid.

Now slide an M8 spring washer onto the screw shaft, followed by a flat washer, and then screw on one of the nuts that you took off the binding post to hold it in place.

Once you've attached all six binding posts in this way, remove the four screws holding the touchscreen onto the



The basic mounting arrangement showing how the PCB (in this case without components) attaches to the display PCB via four threaded stand-offs. The six heavy-duty binding post terminals attach to both the front panel and then directly to the PCB, as shown here. It is imperative that the terminals make intimate contact with the PCB tracks and pads.

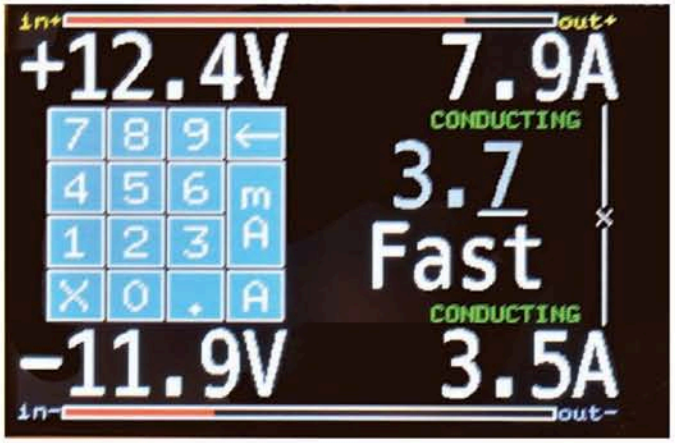


Fig.1: touching the fuse trip current value brings up this keypad which allows you to enter a new trip current value. It can be specified in amps or milliamps and the "X" button cancels the entry, retaining the pre-existing value.

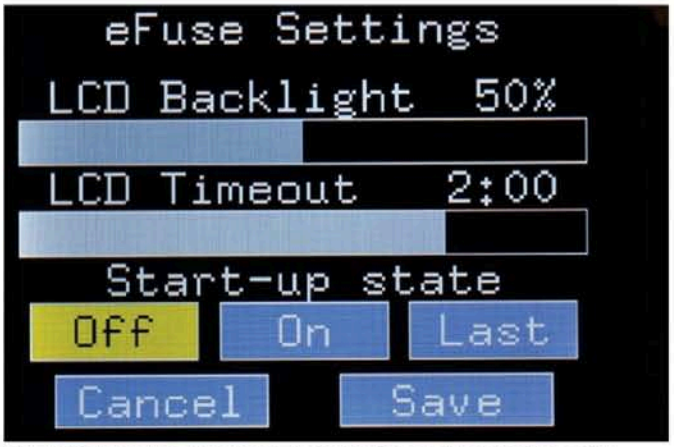


Fig.2: this settings screen is brought up by touching the main screen at left centre and allows you to adjust the LCD backlight brightness, auto-off timeout (which can be disabled) and output start-up state.

eFuse PCB but leave the screen in place. Feed each screw (8-10mm long) through the screen mounting holes in the top of the lid, then place the 1mm thick Nylon spacers carefully on top of the four corresponding holes on the touchscreen module PCB.

Then slide the six binding post screws through the corresponding holes on the eFuse PCB and carefully lower the lid down into place. Be careful not to bump the Nylon washers out of place, then loosely attach the four screws to the tapped spacers below.

Next, check that the unit is sitting flush on the lid and the nuts holding the binding posts are just resting on top of the PCB surface in each case. Tighten or loosen these nuts as necessary, then do up the four screen mounting screws properly.

Ensure that none of the large nuts short out any adjacent components (the board is designed with sufficient clearance – just – but it's best to check).

Finally, fit the remaining binding post nuts onto the shafts and tighten them up to make good electrical contact with the PCB pads, as well as holding the PCB assembly firmly in place. You can now apply power and check that everything is working before screwing the whole assembly into the bottom of the case using four black self-tapping screws.

Using the unit

The operation of the software has been changed slightly since our last article, so what we describe below is slightly different from what we stated in the last article.

The photo opposite (top) shows the eFuse with its main screen, which appears immediately after power up.

This is the default screen and shows all the relevant parameters which are constantly updated. The input voltages are shown in the upper left and lower left corners, with their positions being physically close to the actual inputs themselves. If there is no voltage applied to the V- input, its reading should be close to zero, as it is here.

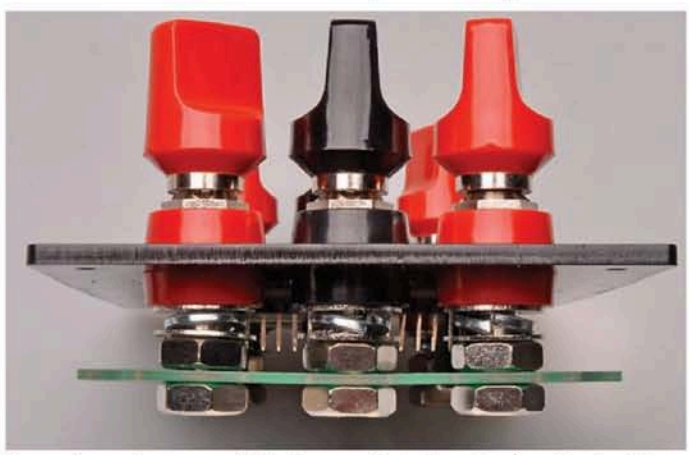
Immediately to the right of these voltage readings, the instantaneous (short-term averaged) current readings are shown for both the positive and negative outputs. If those outputs are off (as they are by default at power-up), then the word "off" appears instead.

The outputs can be switched on and off by simply touching the upper and lower right-hand corners of the screen. If they are linked (shown by an unbroken line between them, along the right edge of the screen) then they will be switched together and they will also trip off simultaneously if either exceeds the programmed current limit. They can be linked or unlinked by touching the centre right edge of the display.

The trip current and speed are shown at centre right. The speed is either "Slow", "Medium" or "Fast" and can be changed simply by touching it; it will cycle through the three possible settings. The trip current is shown above this and you can change it by touching it.

This will bring up a keypad, allowing you to enter a new value in amps or milliamps (see Fig.1). It takes effect immediately after you have finished setting it. If you change your mind, you can cancel and the old setting will be retained.

Note that while making these changes, if the output(s) are still switched on, the unit will continue to operate as normal and protect the load(s). It uses the pre-existing setting as the trip threshold until you have finished setting a new one.



An end-on close-up of the heavy-duty terminals attached to the PCB. Don't forget the spring washers and flat washers on the terminal shafts – they help prevent them working loose.

Fuse trip bars

Because a normal fuse or circuit breaker will not trip instantly when the current flow exceeds the set threshold, the current readings shown are a useful guide

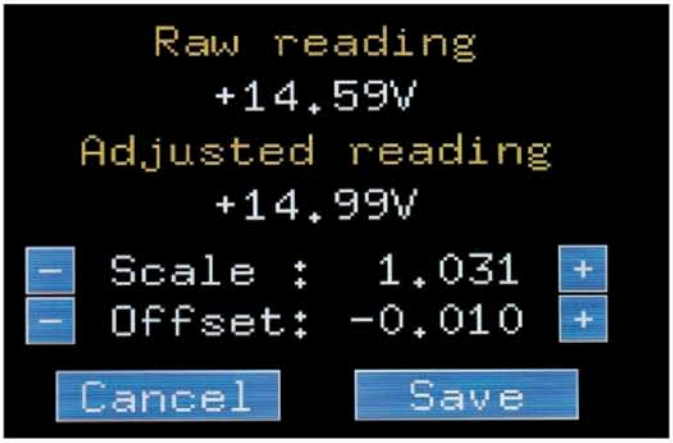


Fig.3: both voltage and both current readings can be calibrated using this screen. It allows you to change the scale factor and add or subtract a fixed value (offset) and see the effects of the changes before saving them to flash.

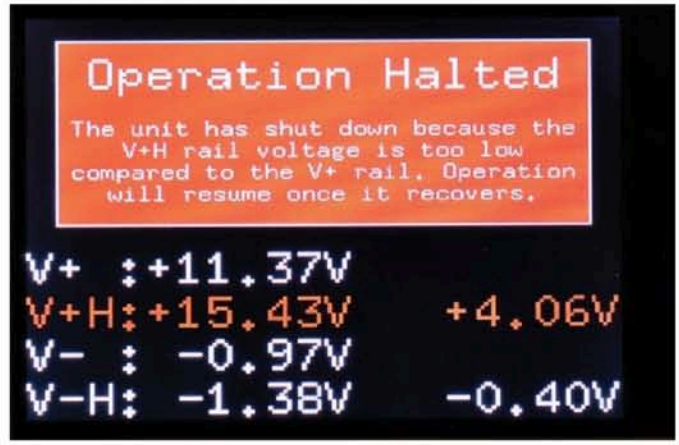


Fig.4: if, at start-up or during operation, the V+, V+H or V-L supply rails are not within their expected ranges, the unit will automatically switch off its outputs and display a screen like this until the fault clears.

but don't necessarily indicate how close the unit is to tripping. Also, they can only update a few times per second or they will become too difficult to read. So to give you a better idea of what's going on, a bar graph is shown along the top and bottom edges of the display.

When either bar reaches the right edge of the screen, the corresponding fuse (top = V+, bottom = V-) will trip off. This is akin to fitting a standard fuse with a temperature read-out and calibrating the scale so that the bottom end is at ambient temperature and the top is at the temperature where the fuse material will melt. So you can quickly see how close it is to tripping and these are constantly updated.

We're also showing temperature readings above and below the voltage readings. These are not the simulated fuse temperatures, they are the estimated temperatures of Mosfets Q1 and Q3.

As stated in the earlier articles, the continuous current rating of this unit is limited by the (unavoidable) heating of those transistors. We don't want them to be damaged so the unit will switch the outputs off to protect them.

These estimated temperatures are used for that protection measure. The data sheet gives a maximum operating junction temperature for the BUK7909 of 175°C (a pretty typical figure for a Mosfet) but since we're estimating these, to be safe, we switch the output off above an estimated 150°C.

We take into account the increase in on-resistance with elevated temperature and also factor in the estimated thermal resistance of the Mosfet packages and heatsinks, along with an estimated maximum ambient temperature of 45°C, accounting for elevated temperatures inside the unit's case during operation. We also monitor the Mosfet gate voltages, since if they drop, this will increase the on-resistance and thus heating.

Backlight control and start-up state

Because the unit draws more power from the positive voltage source when the screen is lit and because you may be using it in a situation where it's left connected long-term, the screen will by default switch off after a period of inactivity. The backlight brightness and time-out settings are shown at centre left and can be changed by touching in this area. This brings up the setting screen (see Fig.2).

Touching anywhere on the screen, including areas which do not have any effect, will reset this timer, as will either of the outputs tripping off. You can turn this feature off (in the settings screen) if you don't need it. Reducing the backlight brightness will also reduce the quiescent current and an estimate of the burden current is shown at centre left (although you can't really see it when the display backlight is off).

The settings screen also lets you select the state of the outputs when the unit is powered up. By default, they are both off.

You can instead set them to retain the last state or to be on by default. Retaining the last state would make sense in a semi-permanent installation where the source power could be lost but you want the load to come back on automatically if it was on when power was lost.

Calibration

Trimpots VR1 and VR2 on the eFuse PCB allow the common mode rejection of the differential current-sensing amplifiers to be optimised but these do not allow other errors to be adjusted out such as scale errors due to resistor tolerances, offset errors due to bias currents and offset voltages or errors in the voltage dividers which allow the unit to measure the input voltages.

These are instead performed digitally, using the touchscreen. All you need to do is set up the unit with a known voltage or current and then hold your finger on the reading which needs to be adjusted (ie, in one of the four corners of the screen) for a couple of seconds. The display will then change to the calibration display; see Fig.3.

This shows you the raw reading for that input, along with two adjustments and the adjusted reading. You can increase or decrease the scale and offset factors so that the adjusted reading shown matches the actual reading.

Note that readings above 9.99V/9.99A are shown in the calibration screen with an extra digit of resolution for easier adjustment.

For example, say you feed exactly 12.00V into the V+ input and you get a reading of 11.70V. Then if you feed 15.00V into V+, you might get a reading of 14.60V. This is an error of -0.3V at 12V and -0.4V at 15V.

Since the difference in error is 0.1V with a difference in reading of 2.9V, you can calculate the scale error as being 0.1V / 2.9V = 0.034 and so you can then increase the scale factor to 1.034 and make the measurements again.

This time you should find that the readings you get are something like 12.1V for a 12V input and 15.1V for a 15V input. Since the error is now the same in both cases, that means we have set the scale value correctly (otherwise, nudge it slightly up or down and try again). It's then just a matter of setting an offset of -0.1V and the readings should be correct.

Press "Save" to save the calibration to flash memory.

You can then repeat this procedure so that both input voltage and both current readings are as close as possible to being correct.

Note that calibrating the current readings can be a little tricky due to noise. The software is designed so that with VR1 and VR2 adjusted correctly and the other calibration settings made correctly, you should get a 0A reading for both outputs with no load.

We have to take noise in the measurement system into account when making the calculations since this is overlaid on the current measurements.

But you may find you get a non-zero reading with no load and this is a good thing to check once you have finished calibration.

If that happens, the easiest solution is to slightly reduce the offset setting for the relevant output(s) to bring the reading closer to zero. This may lead to a small error at higher currents but you shouldn't need a very large offset (hopefully well under 100mA) to get a zero reading. If you do need a larger adjustment, that suggests that some other aspect of the calibration is off, so go back and check it again.

It is important to get the CMRR adjustment correct; if you get a zero reading with no load with an input voltage of say 12V but a non-zero reading at say 30V (or vice versa), that strongly suggests that the CMRR is not good and you need to tweak VR1/VR2 to fix this, then re-check the software calibration.

Start-up self-checks

While not shown on the main screen, the unit constantly monitors the V+H and V-L voltage rails to make sure that they come up to an appropriate voltage before it begins operation and that they do not drop to the point where the unit will not work correctly.

If the V+ supply voltage is not high enough for the unit to operate properly, it will not start up and will display a message indicating this (see Fig.4).

Should V+ drop too far during operation, the outputs will automatically be switched off and a similar message displayed. This is to protect the unit itself, since, with a low V+, the Mosfets could go into partial conduction, causing excessive heating.

Likewise, if a construction error prevents the V+H or V-L voltages from coming up correctly, at power-up the unit will refuse to operate and will display a message indicating this and showing the voltages. In this case, you will need to switch off and check your construction.

If for some reason these voltages drop too much during operation (eg, due to a dud component), the outputs will again switch off and a similar message will be displayed.

Conclusion

The software for this project can be downloaded from the SILICON CHIP website and a programmed PIC32 microcontroller will be available from the SILICON CHIP on-line shop.

How the software works

We won't go into too many details about the BASIC code which drives the display, handles touch and basically provides the "user interface" for the eFuse. It's all pretty standard MMBasic code and if you're interested, you can download the source code and have a look at it.

What made the software a bit tricky for this project was the fairly complex CFUNCTION that we had to build. That's because we need the unit to be checking the current flow at both outputs several thousand times per second in order to switch the output off if it exceeds the programmed limits. We can't really rely on BASIC code to do that as it wouldn't be fast enough and the timing may not be precise.

So what we do is call a CFUNCTION at the start of the BASIC code which sets up the analog-to-digital converter (ADC) in the PIC32 to automatically scan the relevant inputs (four to monitor voltages and two for currents) and convert the voltages at those inputs to digital values.

We have also set up the main hardware timer, timer 1, to generate periodic interrupts and we check whether the ADC has finished scanning and converting the programmed inputs. If it has, we extract the values from special registers and add them into a set of accumulation registers, as well as keeping track of how many times this has been done.

We've had to use the timer because MMBasic doesn't give CFUNCTIONs access to most interrupts and that includes the ADC conversion completed interrupt. As long as the timer interrupts are frequent enough that it won't miss an ADC conversion complete event, this isn't an issue.

The BASIC code can then call the CFUNCTION with a different set of parameters to retrieve these values and it can then divide the accumulated values by the number of times they have been accumulated to get average readings for each input. It simultaneously resets these accumulators, ready for the next conversion.

Fuse trip logic

We've built the fuse trip logic into the timer interrupt routine, so that no matter what the BASIC code is doing, if the current flow goes too high or the simulated fuse temperature reaches its limit, the output(s) will be switched off. The BASIC code periodically checks if this has happened and has the ability to then "reset" the fuse later, through another CFUNCTION call.

This also has the advantage that the mathematics required to simulate the action of a fuse can be handled efficiently with C code, which is important since the calculations are updated thousands of times per second.

There's one final trick to the CFUNCTION and that is that the pin we have used to control the LCD backlight, pin 18 (RB9) is not one of the Micromite's PWM outputs. But we want to use PWM to control the backlight brightness. The reason we didn't use a PWM pin for the backlight is that all PWM pins are also analog inputs on the LCD BackPack, and we needed every single analog capable input for measuring voltages.

Incidentally, the PIC32 chip used for the Micromite has a limited capability to re-assign pin functions, meaning that it would theoretically be possible to use other pins for PWM but the Micromite firmware does not currently support this.

Anyway, our solution is simply to use the timer 1 interrupt, which we have already had to set up to monitor the ADC state anyway, to pulse this pin with a programmable duty cycle and that allows us to control the backlight brightness while only using up a small number of extra CPU cycles. SC

Safer Homes, Save Money!

Setting hot-water thermostats

Want to save money while making your home safer for children and older people? You can do this simply by reducing the thermostat setting on your electric hot-water system. And why would you want this done? Simply because most hot-water systems are set at too high a temperature, often presenting a risk of scalding.

by LEO SIMPSON

To be specific, hot water that is at or above 60°C can cause scalding in the wrong circumstances.

Consider if an older person is having a shower and accidentally bumps the cold water tap so that the shower suddenly runs very hot. The person might be unable to quickly step out of the torrent of hot water and may not be able to quickly turn off the hot tap.

In fact, they might suddenly lose their balance and fall over in the shower, in which case they may be even less able to avoid the hot water. This could lead to very serious scalding which could mean a stay in hospital . . . or worse!

Or consider a young child in the bath and cavorting about, as they are wont to do. They could easily bump or turn on the hot tap and get a blast of hot water which could be very dangerous to their delicate skin and they can very easily get third-degree burns.

Third-degree burns, by the way, are sometimes known as full thickness burns. They go through the epidermis (outer layer of skin – first degree) and the dermis (lower layer of skin – second degree) and affect deeper tissues. If enough of the body is involved, they are considered life-threatening.

(Never, ever, take hot water temperature for granted when running a bath for young children. Always test the temperature with your elbow to see if it is OK; your elbow is more sensitive than your hand. Then make sure that even if the child does turn on the hot water tap, that it will first run cold. But you need to be present at all times when young children are in the bath!)

A typical thermostat, fitted to a hot water heater. The temperature adjustment control (circled in yellow) goes from 50° (too cold!) to 80° (way too hot!).

There are two requirements to avoid scalding. First, no hot water tap in a home should be able to deliver water at a higher temperature than 50°C. But setting your hot water tank's thermostat to 50°C is (usually) definitely not recommended.

Why? Because tank temperatures below 60°C can encourage the growth of Legionella spores. So the tank thermostat should be set to 60°C, no less. But there are a few qualifications in this requirement.

If the pipe run from the hot water tank is long, and/or is either poorly insulated or not insulated at all, it may mean that the water temperature drops to an unacceptable level before it arrives at the closest tap or mixer.

In that case, the thermostat should be set higher to ensure that the closest tap delivers water at no higher than 50°C .

Why aren't hot-water systems set to 60°C as a matter of course? These days any new tank should have the thermostat set by the installer to 60°C but it appears that in many cases this

The interesting part about this thermostat is that lugs on the temperature adjustment control (orange, in centre) prevent it from being set outside the range of 60° to 75°C, despite the 50-80° clearly visible on the dial.

requirement is ignored and tanks can come from the manufacturer with the thermostat set at 70°C and above.

This really can cause scalding to anyone, let alone more vulnerable children and older people.

If your hot water seems too hot, the solution is to reduce the thermostat to around 60°C. Strictly speaking, this should only be done by an electrician or a plumber qualified to do the electrical and plumbing work for electric hot-water systems.

But this can be done very simply and safely in just a few steps.

(1) Go to your meter box and switch off the circuit breaker for the hot-water system.
(2) Remove the plate on the tank which has the entry point for the electrical connections.
(3) Identify the thermostat dial and check its setting.
(4) If it is above 60°, use a flat-bladed screwdriver with an insulated shaft to rotate the thermostat dial to 60°C. (Most tank thermostats now have a minimum temperature setting of 60°C).
(5) Replace the plate on the hot-water tank.
(6) Turn on the circuit breaker for the hot-water system.

Note that while the thermostat on older hot-water systems is relatively easy to identify, the thermostat "dial" on new systems can be much smaller and the numbers harder to read.

However, even setting your hot water tank thermostat to 60°C may still result in tap water temperatures above 50°C.

If this occurs, the outlet of the hot water tank should be fitted with a water tempering valve (see above). This is defintely a job for your local plumber.

By the way, the only way to be sure that your water temperature, as delivered by the tap closest to the tank, is 50°C or less, is to measure it with a mercury thermometer or a calibrated thermocouple and digital multimeter. (Do not use a meat thermometer – they are not sufficiently accurate.)

Energy saving

Reducing the thermostat setting by 5 or 10°C will give an energy saving over a year of use. But unless you have an electric hot-water system which permanently powered, ie, not off-peak, the cost saving is not large.

The main reason for reducing the thermostat setting to 60°C is to reduce the risk of scalding.

There is another possible benefit of having a lower temperature setting in that there will be lower stresses in the tank due to heating and cooling and this applies particularly to larger tanks which are usually run overnight to benefit from off-peak tariffs.

Will the tank last longer? Maybe. But you also need to ensure that the sacrificial anode is replaced at every five years or so (something that even many plumbers don't know about!).

See our articles on this topic in the November 2012 issue: siliconchip.com.au/Article/417 and siliconchip.com.au/Article/409

By the way, electric hot-water systems are being phased out and are usually not allowed to be installed in new homes where solar and gas hot-water systems are used instead.

Nevertheless, these should also be set to ensure that hot water inside the home is no more than 50°C. SC

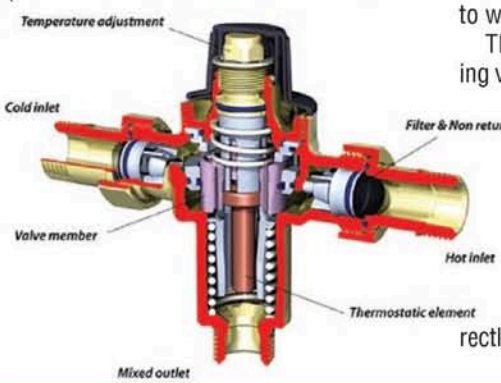
Tempering valves

This article would not be complete without mention of tempering valves. These devices mix hot and cold water to achieve a pre-set temperature, (usually) set by rotating a knob.

While generally not required where the system delivers hot water to existing dwellings at less than 50°C in bathrooms, the Plumbing Code of Australia (PCA) requires that the delivery temperature of hot water for personal hygiene purposes (primarily bathroom taps) is not to exceed 45°C for early childhood centres, primary and secondary schools, and nursing homes or similar facilities for young, aged, sick or disabled persons.

Considering that the PCA also requires a minimum tank temperature setting of 60°C (Australian Standard AS3500.4.2 Clause 1.6), the 45°C requirement can only be met by the fitting of tempering valve.

A typical Tempering Valve with adjustment under the blue dust cover.



These valves have an inbuilt thermostat element and a sliding valve that varies the ratio of hot and cold water that is allowed to pass. The temperature setting can be adjusted and is typically controlled to within ±3%.

The PCA also now requires that tempering valves be installed on all **new homes or renovations**.

So, when an old hot water system is replaced, a tempering valve should also be installed, to reduce the temperature to 50°C in bathrooms.

Kitchen and laundry applications are still permitted to bypass the tempering valve and use the hot water directly from a standard electric or gas heater.

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Modifications to Mains Power Supply for Battery Valve Radio Sets

Some battery-powered valve radios (such as the HMV 1955 portable model 12-11 featured in Vintage Radio this month) have their heater filaments wired in series.

This requires an "A" battery of either 7.5V (four valves) or 9V (five valves). The Mains Power Supply for Battery Valve Radio Sets presented last month provides either a 1.5V or 2.0V filament voltage.

So if you want to power one of the radios with series-connected heater filaments, you will need to make a few modifications to the unit, as shown here.

The two 6V secondaries of transformer T2 are now wired in series, rather than parallel and the resistors which set the regulated output voltage between A+ and A- are changed so that you get 9V with JP1 in and 7.5V with JP1 out.

The only other components which are changed are the series current limiting resistor for LED1; which is increased to 2.2kΩ to cope with the higher supply voltage, and the resistor feeding ZD1 which is increased from 470Ω to 1.5kΩ for the same reason.

All the component changes besides the changed connections for T2's secondary are shown in red on the accompanying circuit diagram.

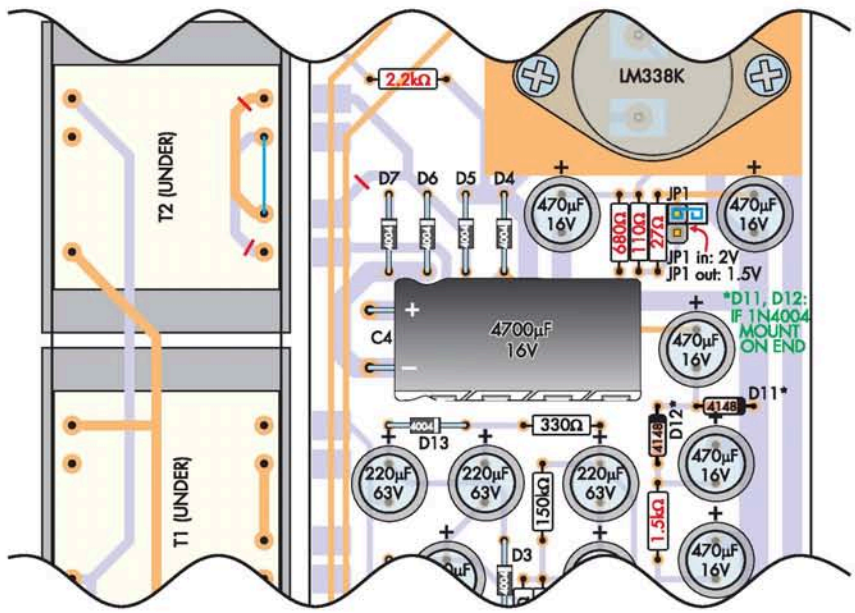
The partial PCB overlay shows how to make the changes. The three track cuts are shown in red; these are most easily done before the unit is assembled since one of these tracks is underneath transformer T2, when it has been assembled.

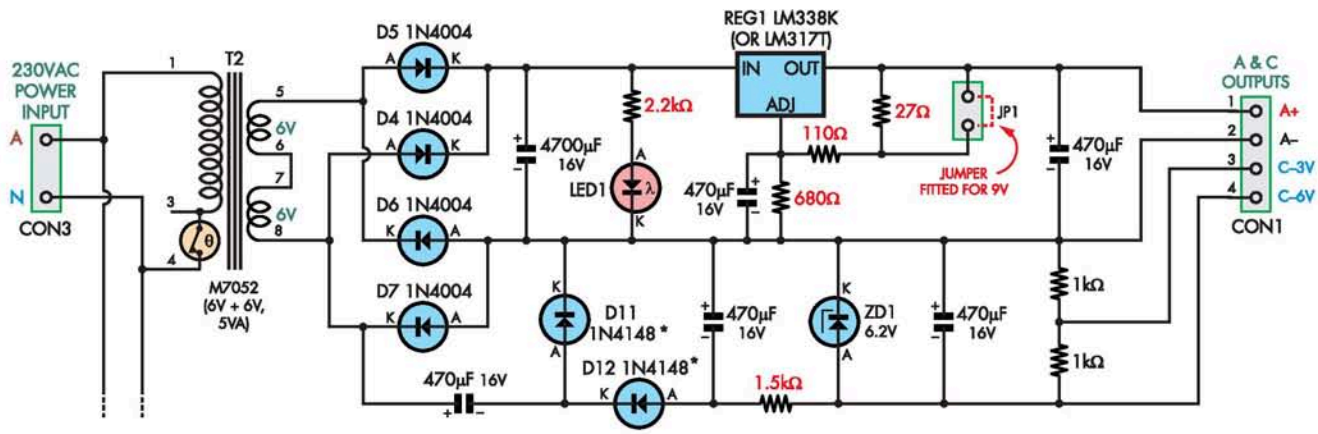
Make sure these tracks are properly severed and once T2 has been mounted, add the wire link shown in blue. It's then just a matter of making the five resistor substitutions shown.

Note that when adding the wire link for T2, it's easiest to do this underneath the main board since if you do it on the transformer mounting board, you may then have trouble soldering this board onto the main board.

Having made the changes, it's recommend that you block off the 1.5V/2V output socket on the front panel and clearly label the power supply as having a 7.5V or 9V output, to ensure that it isn't accidentally connected to a set requiring 1.5V or 2.0V, as this could damage the set and/or the power supply.

Ian Robertson,
Belrose, NSW. ($50)





VALVE POWER SUPPLY MODIFICATIONS FOR SERIES HEATER FILAMENTS

Recalibrating the oscillator in a PIC12F675 or PIC12F629

The Microchip PIC12F629 & PIC12F675 microcontrollers require the internal oscillator calibration value to be preserved during programming.

A failed programming attempt can corrupt this value, resulting in a chip which is unusable if you need it to run off its internal oscillator.

The calibration value is used to keep the internal oscillator running within specifications. It's supposed to operate between 3.8MHz to 4.2MHz over the full supply voltage (2.5-5.5V) and temperature (-40°C to +85°C) ranges. Note that the "-E" extended temperature versions can operate at up to +125°C.

The calibration value is preprogrammed by the manufacturer and can differ between one device and another. This calibration value is located in the last byte of the program memory (at address H3FF) and the instruction in that location is a "retlw XX".

This means that a program call to that location will return with the value "XX" located in the "w" register.

Before programming, the entire program memory must first be erased and if the value at address H3FF is not read and stored first, it will be lost.

Typically, a PIC programmer such as the PICkit 3 will read the value before erasing the flash memory and then re-instate this value at the end of the programming process.

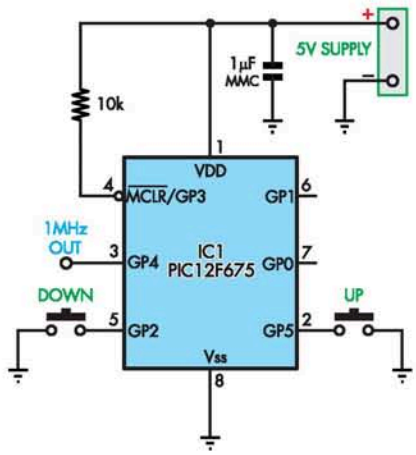
A program running on one of these processors will normally include the following instructions which read the stored calibration value and place it into the special register OSCCAL:

```
bsf STATUS, RP0 ;Bank 1
call 3FFh ;Get the cal value
movwf OSCCAL ;Calibrate
bcf STATUS, RP0 ;Bank 0
```

The circuit and the software described here can be used to restore a suitable calibration value when the original is either erased or corrupted. The program is called "osccon adjust.asm" and is available for download from the SILICON CHIP website.

To recover the calibration value, you need to program the PIC with this software and then monitor the oscillator signal at pin 3.

The program sets up the PIC to produce a frequency at this pin which is the internal oscillator frequency divided by four and so it should produce a ~1MHz (950kHz to 1.05MHz) signal when the calibration value is correct. You will need an oscilloscope or frequency meter to read the frequency.



PIC12 CALIBRATION

If you load this software and find that the frequency is incorrect, the Up and Down switches are used to alter the OSCCAL value until the required frequency is found.

Pressing and holding down a switch will alter the value at about one increment per second.

Once the frequency is correct, the required calibration value is then located at the first (H00) EEPROM location and this can be read using a PIC programmer.

So once you have the correct frequency, read the EEPROM contents and then use the "view EEPROM" function to see this value. You can then store it at memory location H3FF to restore normal operation.

Note that if the value at H3FF is invalid (such as 3FFF, for an erased value) then you will need to choose an initial valid value since otherwise, you can't program the PIC.

You can check if the value is valid by reading the program memory and then using the "view program memory" function and scrolling to the calibration value at the last location (3FF).

The memory in this location should be 0x34XX (ie, 34XX hexadecimal), where the 34 is the "return literal with a value in W (RETLW)" instruction and XX is the OSCCON calibration value.

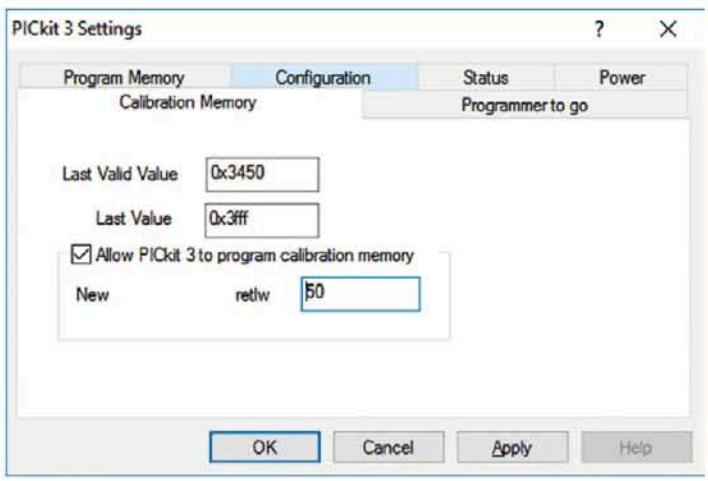
Typically, the XX value is somewhere in the middle between the minimum of 00 and maximum of FF. A good default value to use would be 50, ie, 0x3450.

The screenshot (shown below) shows the settings for use with a PICkit 3 to program the calibration value. Select programmer/settings/calibration memory and ensure the box "Allow PICkit 3 to program calibration memory" is ticked and the calibration value has been typed in.

This should be the same as the value found in EEPROM (if you successfully ran the calibration program) or a suitable default value such as 50 if your calibration value has been lost. You will get a warning message once you press OK. Simply press OK again to program the calibration value.

Don't forget to uncheck the "Allow PICkit 3 to program calibration memory" option when you've finished. The assembled software ("osccon adjust.HEX") is available from the SILICON CHIP website.

John Clarke,
SILICON CHIP.



Configuring the PICkit 3 for the calibration value needed in a PIC12F675 or PIC12F629. We've used a default calibration value of 50 hex (8-bit value) and the option "Allow PICkit 3 to program calibration memory" must be ticked.

Bipolar transistor tester, Mk2

Regular readers of SILICON CHIP may recall the PICAXE-based bipolar transistor tester, published in the Circuit Notebook section of September 2016 (www.siliconchip.com.au/Article/10144).

This new design does the same job, but the PICAXE14M2 microcontroller has been replaced by a 74HC14 hex schmitt trigger inverter. That makes this version easier to build as there is no programming involved.

This project combines three simple circuits into a complete tester for both NPN and PNP transistors. It will show transistor polarity, locate junction faults, identify the pins and give an idea of transistor gain.

The device under test (DUT) is clipped into the test lead clips and then the lead is plugged into the test sockets in the following order: DUT1 (the base tester), DUT2 (the fault tester) and then DUT3 (the gain tester).

We will describe how each of the three test sections is used first, then explain how they work later.

The base tester identifies the base pin and shows if the transistor is an NPN or PNP type. The circuit includes a red and green LED for each pin of the transistor and both LEDs will turn on for the emitter and collector pins while a single LED will turn on for the base pin. The green base LED lights for an NPN transistor or the red LED for a PNP transistor.

Having determined which transistor pin is the base, make sure it's connected to the middle test lead clip before moving to the fault tester.

The fault tester finds faulty junctions and also shows if the transistor is an NPN or PNP type. A good NPN transistor lights the green LED in this section and a good PNP transistor lights the red LED.

This tester is able to indicate open or shorted collector-emitter or base-emitter junctions. Both LEDs turn on with an open junction and both LEDs are off with a shorted junction. If a test transistor is not fitted, both LEDs turn on (ie, this is equivalent to an open junction).

The gain tester identifies the emitter and collector pins and gives an idea of the transistor gain. Test the gain by rotating S2 to select the highest value base resistor that will fully illuminate the green LED (NPN) or red LED (PNP). The higher the resistance that can be selected for full LED brightness, the higher the transistor gain.

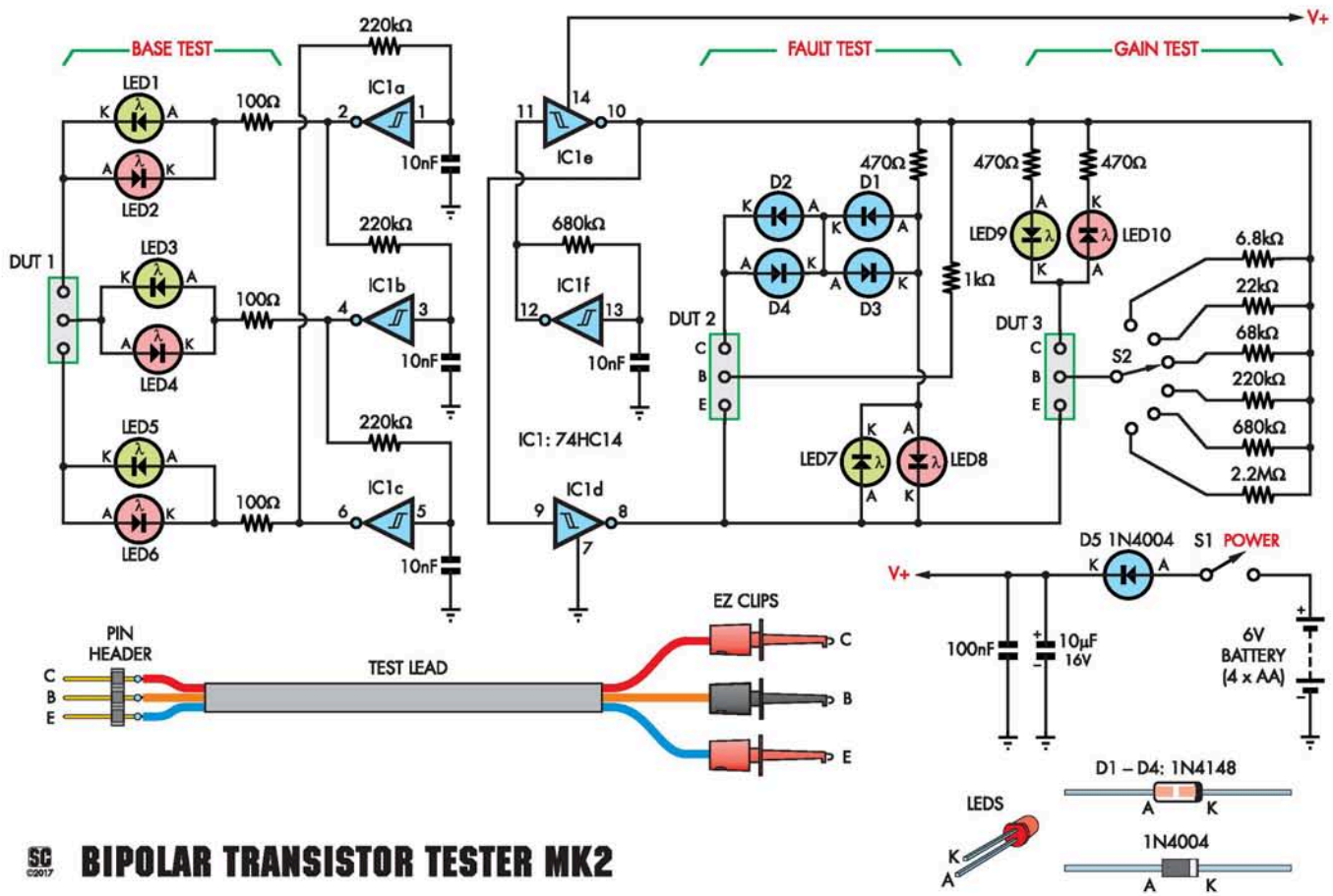
The correct orientation of the transistor (ie, collector to C and emitter to E) will give a higher gain reading. So if you reverse it and the gain drops (ie, the LED is dimmer) then swap it back again.

The base tester

This base tester section works by switching the three transistor pins at DUT1 between a low and high state at different times, via a schmitt trigger ring oscillator based on inverters IC1a-IC1c.

This gives six different voltage combinations: high/low/low, high/high/low, low/high/low, low/high/high, low/low/high and high/low/high.

Consider an NPN transistor being tested. When its collector and base are driven high and the emitter is pulled low, current will flow from the collec-



tor to the emitter, lighting two LEDs.

When the collector and emitter voltages are reversed, the collector and emitter switch roles. While the transistor will have a much lower gain and breakdown voltage when operated "in reverse", it will still allow current to pass between collector and emitter, so the other pair of collector/emitter LEDs will light.

But at low voltages, the base current for an NPN transistor can only flow from the base to one of the other two terminals.

Hence, for an NPN transistor, only one of the base LEDs will light (ie, green). And the same is true in reverse for a PNP transistor, so it will light the red LED.

The fault tester

The fault tester is based on an oscillator involving inverter IC1f, the output of which is inverted by IC1e. This produces two square waves 180° out of phase.

One square wave is applied to the B and C terminals of DUT2, current being limited by separate resistors. The opposite polarity square wave is applied to the E terminal.

LED7 and LED8 are connected in inverse parallel so that, by default, LED8 (red) will turn on when the B/C pins are high and E is low, while LED7 (green) switches on in the opposite condition.

But the device under test will short out one of these LEDs if it's operating normally, by conducting current through diodes D1-D4.

If the DUT is NPN, it will switch on when the collector/base are high and emitter is low, shorting out LED8 but allowing LED7 to light. And for a PNP transistor, the reverse is true.

A shorted transistor will short out both LEDs, while an open-circuit transistor will short out neither.

As noted earlier, transistors will operate in a fashion even if their collector/emitter terminals are swapped, so if the collector and emitter are swapped, the circuit will still work as expected.

Diodes D1-D4 provide a ~1.4V voltage drop which stops current flowing through a simple diode junction within the DUT from shorting out either LED. The DUT must operate like a transistor and have reasonable gain in order to short out either LED.

The gain tester

The operation of the gain test stage is fairly simple; switch S2 sets the source resistance and therefore base current and this, multiplied by the transistor's gain, determines the LED (collector) current and therefore brightness.

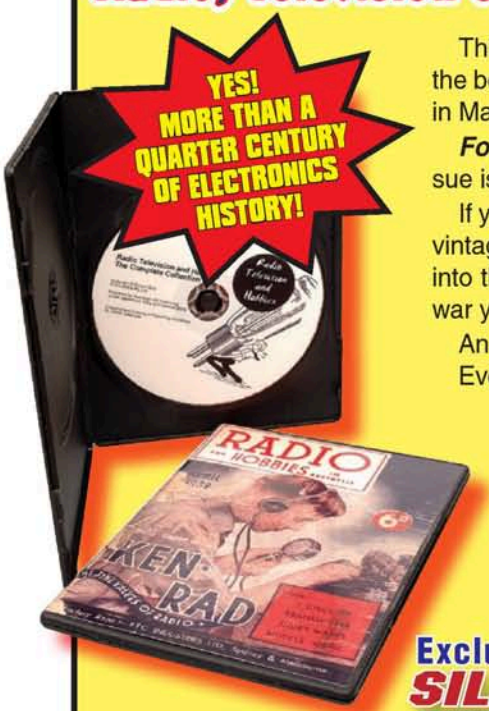
This whole device runs from a 6V battery (four AA cells) which is controlled by power switch S1. Diode D5 drops the supply voltage to just over 5V and also provides reverse battery protection.

The prototype used 3mm clear-lens LEDs as these tend to be more efficient than the diffused lens type. Headers used for the test sockets were cut from Arduino Shield Strips (Jaycar HM-3207).

These headers have long pins, allowing the test sockets to be level with the enclosure lid.

Ian Robertson,
Engadine, NSW. ($50)

Radio, Television & Hobbies: the COMPLETE archive on DVD



This remarkable collection of PDFs ***covers every issue*** of R & H, as it was known from the beginning (April 1939 – price sixpence!) right through to the final edition of R, TV & H in March 1965, before it disappeared forever with the change of name to EA.

For the first time ever, complete and in one handy DVD, every article and every issue is covered.

If you're an old timer (or even young timer!) into vintage radio, it doesn't get much more vintage than this. If you're a student of history, this archive gives an extraordinary insight into the amazing breakthroughs made in radio and electronics technology following the war years.

And speaking of the war years, R & H had some of the best propaganda imaginable!

Even if you're just an electronics dabbler, there's something here to interest you.

- **Every issue individually archived, by month and year**
- **Complete with index for each year**
- **A must-have for everyone interested in electronics**

ONLY $62.00 +$10.00 P&P

Exclusive to: SILICON CHIP

Order now from www.siliconchip.com.au/Shop/3 or call (02) 9939 3295 and quote your credit card number.

Using a 5-inch touchscreen with the Micromite Plus Explore 64

The Micromite Plus Explore 100 (September-October 2016; www.siliconchip.com.au/Series/304) is designed to allow a 5-inch 800 x 480 pixel full-colour touchscreen to plug right in and the Micromite Plus software contains all the routines needed to drive that display and sense touch.

By comparison, the Explore 64 (August 2016; www.siliconchip.com.au/Article/10040) is a much more "bare bones" project with a tiny PCB that only has just enough parts to operate and there's no provision for plugging in a touchscreen.

But it uses a very similar microcontroller to the Explore 100 and the same software, so of course, it's possible to hook a touchscreen up to the Explore 64 too.

In fact, this was the topic of a question asked by C. B., of Many-peaks, WA in the Ask SILICON CHIP section of the June 2017 issue (page 107). That's because working out how to make the connections isn't easy, since the Explore 64 and Explore 100 pinouts vary.

The circuit shown here demonstrates everything you need to connect the same 5-inch touchscreen as used with the Explore 100, to the Explore 64.

The assembled Explore 64 module is shown at left while the 40-pin connector for the display is shown at right. It's possible to make these connections on a piece of prototyping "stripboard".

Alternatively, you could use a prototyping board with separate pads for each pin and make the connections using point-to-point wiring. Note the requirement of a 10kΩ pull-up resistor for the display's "RD" pin.

It's important to figure out how the display will be connected physically before doing the wiring. That's because the display's DIL pin header is on the back of the module. So you may need to reverse the orientation of the connections if you are using a socket to plug the screen into.

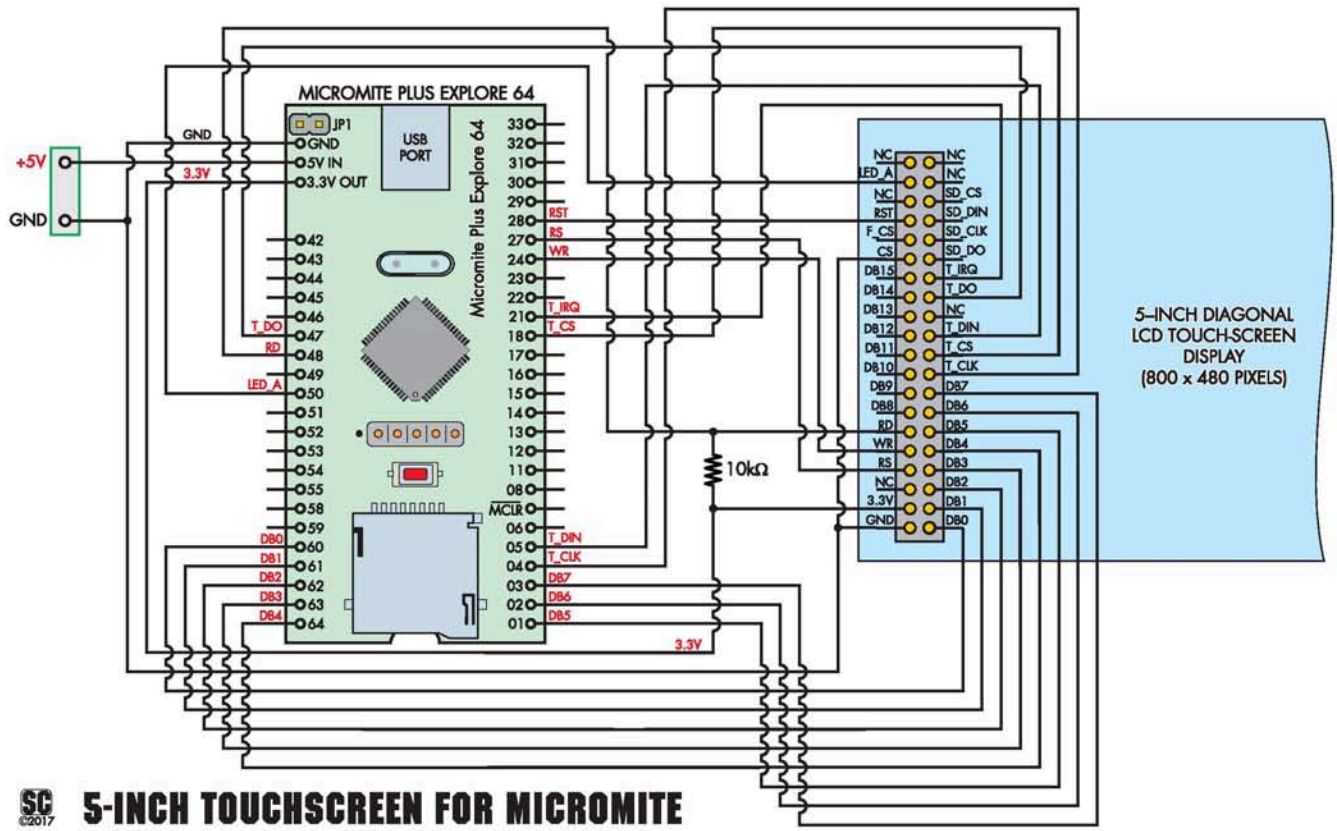
The alternative is to wire up the Explore 64 to a male pin header and use a 40-wire ribbon cable fitted with IDC connectors to connect that header to the one on the display.

The following commands are required to set the display up once it has been wired to the Explore 64. These only need to be entered once:

```
OPTION LCDPANEL SSD1963_7,
  LANDSCAPE, 50, 49
OPTION TOUCH 18, 21
OPTION SDCARD 12, 14
OPTION LCDPANEL CONSOLE
OPTION COLOURCODE ON
```

Note that this display arrangement supports transparent text and the BLIT command; see the Micromite Plus user manual for more details.

Ted Price,
Bondi Junction, NSW. ($65)



SC ©2017 **5-INCH TOUCHSCREEN FOR MICROMITE**

Circuit Ideas Wanted

Got an interesting original circuit that you have cleverly devised? We need it and will pay good money to feature it in the Circuit Notebook pages. We can pay you by electronic funds transfer, cheque (what are they?) or direct to your PayPal account. Or you can use the funds to purchase anything from the SILICON CHIP on-line shop, including PCBs and components, back issues, subscriptions or whatever. Email your circuit and descriptive text to editor@siliconchip.com.au

Subscribe to SILICON CHIP and you'll not only save money but we GUARANTEE you'll get your copy!

When you subscribe to SILICON CHIP (printed edition) in Australia, we GUARANTEE that you will never miss an issue.

Subscription copies are despatched in bulk at the beginning of the on-sale week (due on sale the last THURSDAY of the previous month). It is unusual for copies to go astray in the post but when we're mailing many thousands of copies, it is inevitable that Murphy may strike once or twice (and occasionally three and four times!).

So we make this promise to you: if you haven't received your SILICON CHIP (anywhere in Australia) by the middle of the month of issue (ie, issue datelined "June" by, say, 15th June), send us an email and we'll post you a replacment copy in our next mailing (we mail out twice each week on Tuesday and Friday).

Send your email to: missing_copy@siliconchip.com.au

- ✔ Remember, it's cheaper to subscribe anyway . . . do the maths and see the saving!
- ✔ Remember, we pick up the postage charge – so you $ave even more!
- ✔ Remember, you don't have to remember! It's there every month in your letter box!
- ✔ Remember, your newsagent might have sold out – and you'll miss out!
- ✔ Remember, there's also an on-line version you can subscribe to if you're travelling.

Convinced? We hope so. And we make it particularly easy to take out a subscription - for a trial 6-month, a standard 12-month or even a giant 24-month sub with extra savings.

Here's how: simply go to our website (siliconchip.com.au/subs) – enter your details and pay via Paypal or EFT/Direct Deposit. You can order by mail with a cheque/money order, or we can accept either Visa or Mastercard (sorry, no Amex nor Diners').

If mailing, send to SILICON CHIP, PO Box 139, Collaroy NSW 2097, with your full details (don't forget your address and all credit card details including expiry!).

We're waiting to welcome you into the SILICON CHIP subscriber family!

Vintage Radio

By Associate Professor Graham Parslow

HMV 1955 Portable Model 12-11

If you think the HMV set featured this month looks very similar to the model B61D featured in the June 2017 issue, you are quite right. But even though both sets use the same battery valves, the same case and even the same chassis, there are significant differences in their circuits.

How can that be? Partly this is explained by the fact that the later set has a 4-valve superhet instead of five valves but offsetting this is fact that it can be powered from batteries or from its inbuilt 240VAC mains supply.

Externally, there are few differences between them since the same case was used for a number of HMV portable radio models between 1951 and 1956.

One subtle difference between the 12-11 and B61D is in the brass Little Nipper badge on the front. There is a line across the bottom of the 1955 badge, while the 1951 badge had the words "HIS MASTER'S VOICE" instead. The badge on the model 12-11 does contain those words but they are written in a smaller font, below the image of Little Nipper (the dog listening to His Master's Voice from the gramophone) and above the horizontal bar.

When I received this radio, the exterior was quite grubby but internally it was quite clean. Luckily, the exterior cleaned up well and now matches the clean sound that it produces, which is about as good as a portable of this type can get.

The circuit

The speaker and some other components on my set are stamped February 1955, so this one is reliably dated. Its circuit appears in the 1955 compilation of the Australian Official Radio Service Manual (AORSM) and is reproduced in Fig.1.

Both these sets use the same chassis and the same loop antenna with external aerial coupling. However, there was a welcome change in the later 12-11 set with the use of a plug and socket connection of the aerial to the chassis so that the back can be easily removed. The loop antenna is part of the first tuned LC circuit.

And that is where the first major change to the circuit becomes apparent in that there is no tuned RF amplifier stage and the top of the chassis reveals an unused hole for the missing valve.

At the same time, the tuning condenser is 2-ganged rather than 3-gang and with no RF preamplifier, the tuned signal feeds directly into the control grid (pin 6) of the 1R5 pentagrid frequency changer, V1.

From that point on, the arrangement of the four remaining valves in this largely conventional superhet circuit is quite similar to the B61D model. It has an almost identical 1R5

frequency changer circuit and the intermediate frequency is the same at 457.5kHz.

Neutralisation

This radio has a neutralisation capacitor, shown on the circuit diagram connecting the two grids of the 1R5 via the local oscillator; its value is not specified.

Neutralisation in valve circuits refers to cancelling the effect of internal inter-electrode capacitance in order to reduce its tendency to oscillate and this also usually improves the stage's bandwidth.

Typically the neutralisation capacitor is connected between a point which is 180° out of phase with the anode of the mixer stage and its control grid. Often, a tap on the IF transformer, or the IF transformer secondary is the connection point and so the IF transformer provides the necessary phase inversion. This provides positive feedback at lower frequencies, improving bandwidth.

But at higher frequencies, inherent phase shifts, including those due to the reactance of the neutralisation capacitor, cause this feedback to become negative and this is why it reduces the tendency of the amplifier to oscillate at an unwanted frequency.

In this circuit, the connection of the neutralisation capacitor is a little unusual. V1 drives the local oscillator at 457.5kHz above the tuned station's frequency.

Now the input and output sides of the oscillator are normally 180° out of phase at the oscillator's operating frequency. In this case, they are the anode (pin 2) and grid (pin 4).

So the designers have taken advantage of this existing phase inversion from the anode of V1 and are simply connecting the neutralisation capacitor between the local oscillator and main control grid.

The signal path is slightly different for neutralisation (via C2 rather than C3) but the phase shift of both paths will be similar and hence the neutralisation is effective.

There has been some correspondence to the Editor recently about the subject of neutralising, with much disagreement over exactly how it works. To look into the topic a little more deeply you might like to start with the Wikipedia entry at **https://en.wikipedia.org/wiki/Neutrodyne**

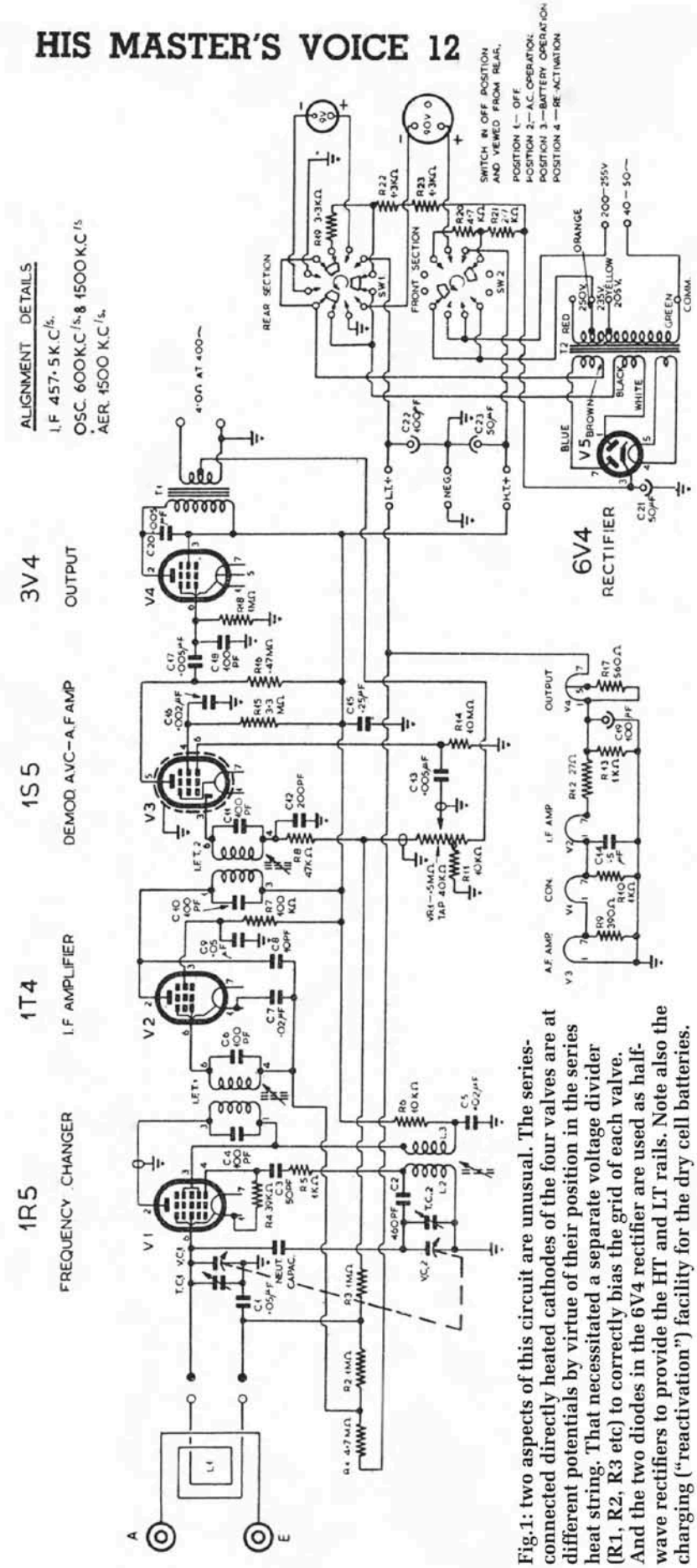
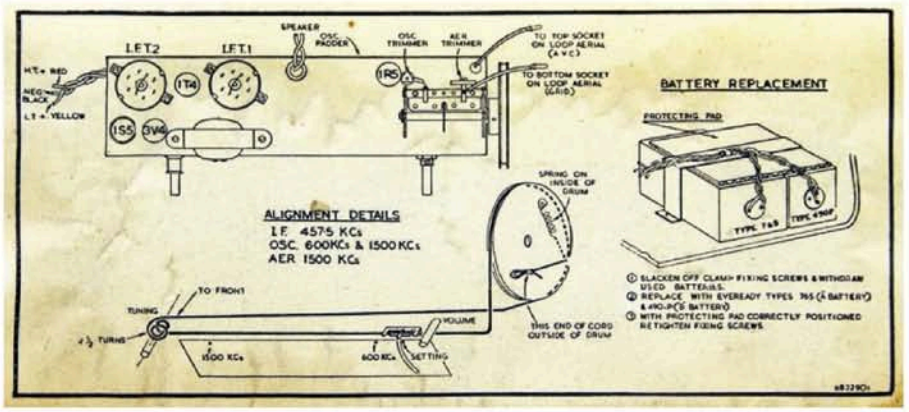


Fig.1: two aspects of this circuit are unusual. The series-connected directly heated cathodes of the four valves are at different potentials by virtue of their position in the series heat string. That necessitated a separate voltage divider (R1, R2, R3 etc) to correctly bias the grid of each valve. And the two diodes in the 6V4 rectifier are used as half-wave rectifiers to provide the HT and LT rails. Note also the charging ("reactivation") facility for the dry cell batteries.



Reproduced from a label stuck to the underside of the chassis, this diagram shows the dial cord stringing arrangement, chassis arrangement, battery replacement instructions and the alignment frequencies.

IF stage and biasing

Moving on now, IF transformer IFT1 feeds the 475.5kHz signal to the 1T4 IF amplifier, V2. This stage is stabilised by shunt capacitor C8.

The amplified signal is demodulated by the diode in the 1S5 valve (V3) and the audio appears across R8 in series with the volume control VR1. The junction of these two resistors becomes more negative under strong signals and this provides feedback for automatic volume control (AVC, otherwise known as AGC).

At this point, it's worth mentioning the somewhat unusual biasing arrangement in this set.

Both mixer/oscillator V1 (1R5) and IF amplifier V2 (1T4) have different negative AVC bias voltages applied to their grids via resistors R1, R2 and R3. V2's screen grid is connected to HT via a decoupling network comprising R7 and C9, while V3's screen is similarly connected to HT via R15, filtered by C16.

Series-connected filaments

All the filaments of the five valves in the earlier B61D model ran from a 1.5V cell but in this set, all the filaments are connected in series to run from a common 9V B supply which can be a battery or the in-built 240VAC mains supply.

Note that these are directly heated cathodes and that means for V1-V4, the cathode connection at pin 1 is shared with one side of the filament (heater). And that means that the cathodes of V1-V4 are all at different potentials. V3's cathode is at ground potential while V1 is higher, V2 higher again and V4 the highest.

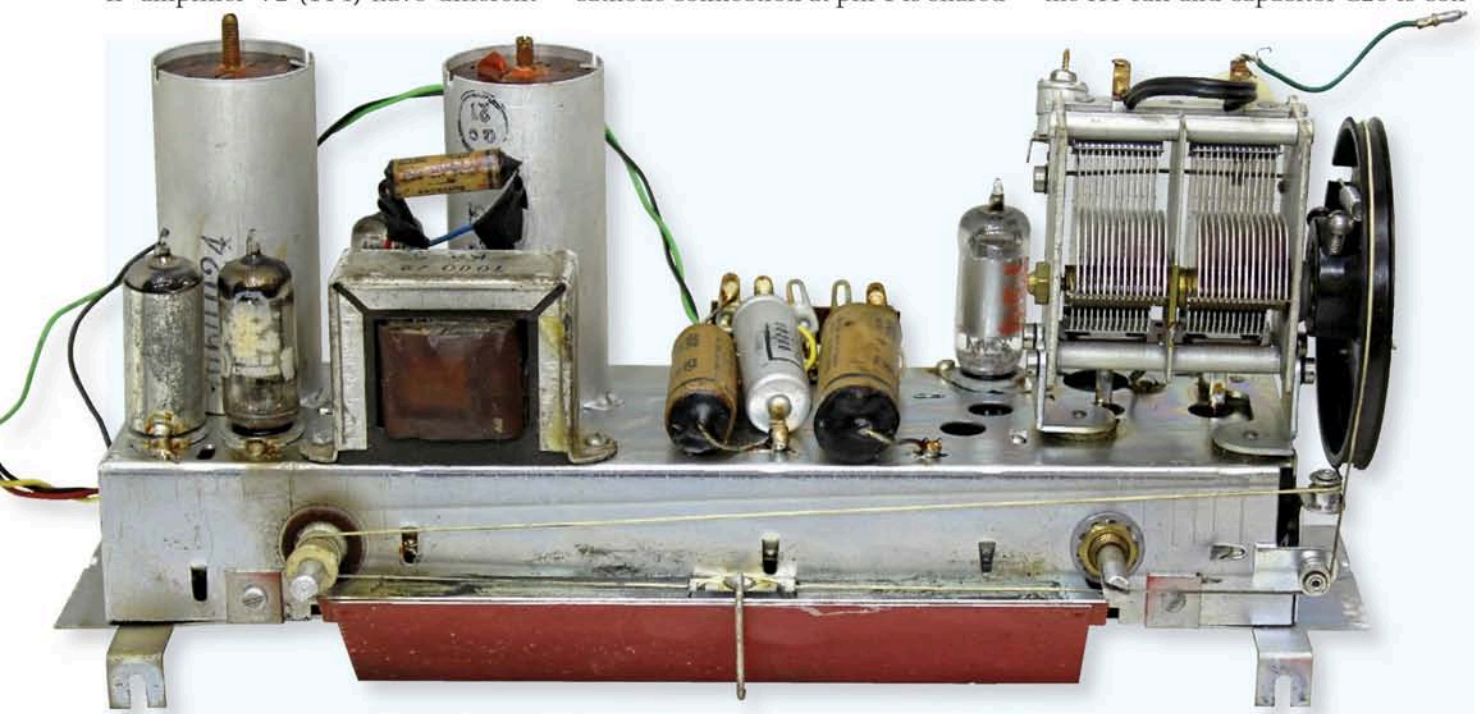
This meant that the designers had to go to special lengths to correctly bias the grid of each valve and this was arranged in two ways. First, while the grid of V4 is connected to chassis via a 1MΩ resistor (R8), the grids of the other three valves connect to a voltage divider comprising three high value resistors (R1, R2 & R3) together with the volume control VR1.

At the same time, three of the four heaters (V1, V3 and half of V4's tapped heater) are shunted with resistors and these have been chosen to fine-tune the grid bias voltages of the various valves. Note the two RC filters in the filament network, to reduce the noise and ripple coupling into the most sensitive stages, V1 and V2.

Audio amplification

Audio from volume control pot VR1 is AC-coupled to the pin 6 control grid of V3 (1S5) which is the first audio amplification stage. The signal is then coupled by C17 to pin 6 of V4, the control grid of the 3V4 output pentode.

V4's screen is connected directly to the HT rail and capacitor C20 is con-



While this is the same chassis as used for the HMV B61D described in the June 2017 issue, the layout is quite different with four valves rather than five, a 2-gang tuning condenser rather than a 3-gang unit and three extra capacitors.

nected across the speaker transformer to limit the audio bandwidth.

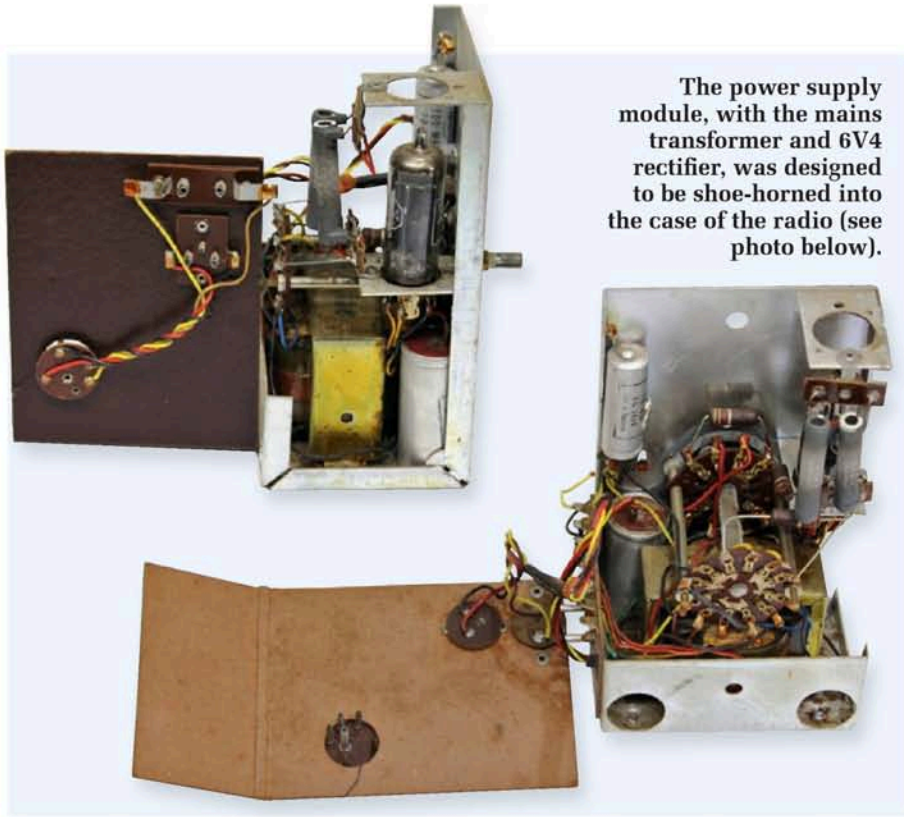
Negative feedback from the speaker output is provided by a centre tap on the output transformer secondary, which is fed back to the bottom of the volume control pot. The volume control is earthed via the output transformer so the signal to the 3V4 valve is diminished by subtracting an out-of-phase waveform.

Resistor R11 is connected between a tap on the volume control pot and ground and presumably helps to ensure that there is no output with the volume control wound fully down and may also serve to linearise the operation of VR1.

Power supply

The separate 240VAC power supply might look conventional, being based on a 6V4 rectifier valve (V5). However, the 6V4's two diodes are cleverly used separately, to produce both the HT and LT rails, providing half-wave rectification for each.

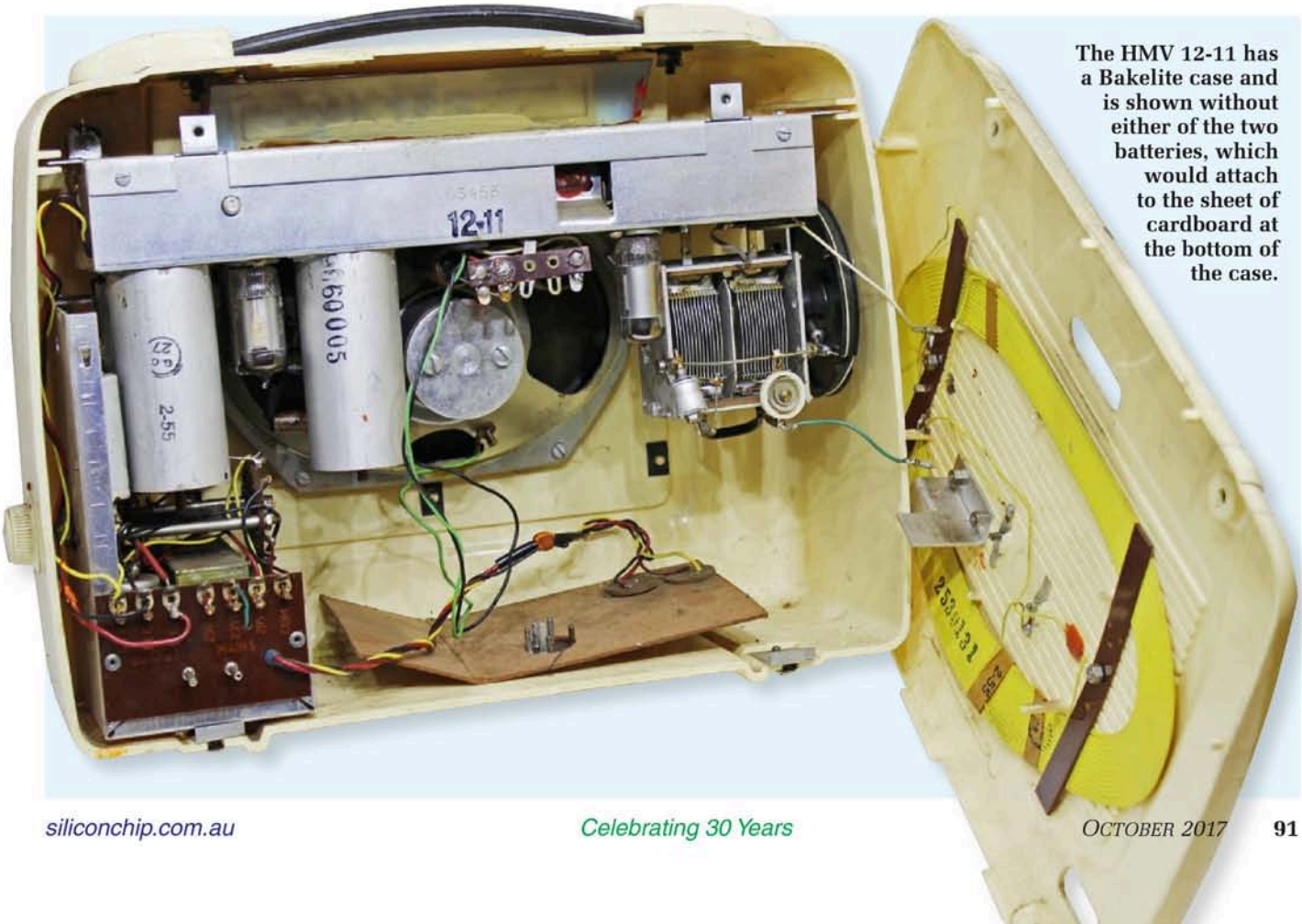
A limit on maximum current and the relatively high internal resistance of the 6V4 rectifier (around 160 ohms) makes a 1.5V supply providing 300mA impractical.



The power supply module, with the mains transformer and 6V4 rectifier, was designed to be shoe-horned into the case of the radio (see photo below).

Instead, the LT unit in this radio produces 20V without load which reduces to 10V under load (close enough to the nominal 9V of the battery). Using a bench supply, this radio drew 55mA at 9V which is close to the AORSM specified value of 47mA.

The HT rail was measured as 79V from the on-board supply, a bit lower than the nominal 90V but this made



The HMV 12-11 has a Bakelite case and is shown without either of the two batteries, which would attach to the sheet of cardboard at the bottom of the case.

little difference to performance as assessed by using a bench supply varied between 80V and 90V.

The power supply simply incorporates series ballast resistors to reduce the voltage to the nominal 9V and 90V rails based on expected current drain. By long-standing convention, the 9V "A" and 90V "B" batteries are physically separate.

The model information glued to the top of the chassis, behind the tuning dial, shows a user how to install Eveready battery types 765 (9V) and 490P (90V).

However, an intriguing extra came with this radio. The two connectors for separately plugging into the "A" and "B" batteries were plugged into an adaptor built on strong cardboard. It served to combine the two plugs into a single plug for a battery pack offering the "A" and "B" batteries in one package.

This seems to have been an innovation for HMV in 1955 because neither the packaged information with the radio nor the AORSM data mention the adapter.

Other manufacturers had used single battery packs from at least 1951. The Eveready type 753 combination battery incorporates a dummy-pin hole, set off-centre to promote correct insertion of the connector.

Battery reactivation

The side of the radio has a knob marked OFF/AC/BAT/RE-ACT. The circuit diagram shows how two Oak wafer switches in the mains power unit control these functions.

In RE-ACT mode, the set is off but the mains power supply is connected across both batteries for trickle-charging, with extra series resistors to limit the charge current to trickle levels. HMV provide the following instructions for battery reactivation:

"After the receiver has been operated on its internal batteries the power switch should be set to the RE-ACT position and the mains supply to the instrument turned on. The period of reactivation should be approximately six hours for each hour of use on dry batteries. As an example a receiver operated for two hours on dry batteries would require twelve hours reactivation and this could conveniently be done overnight."

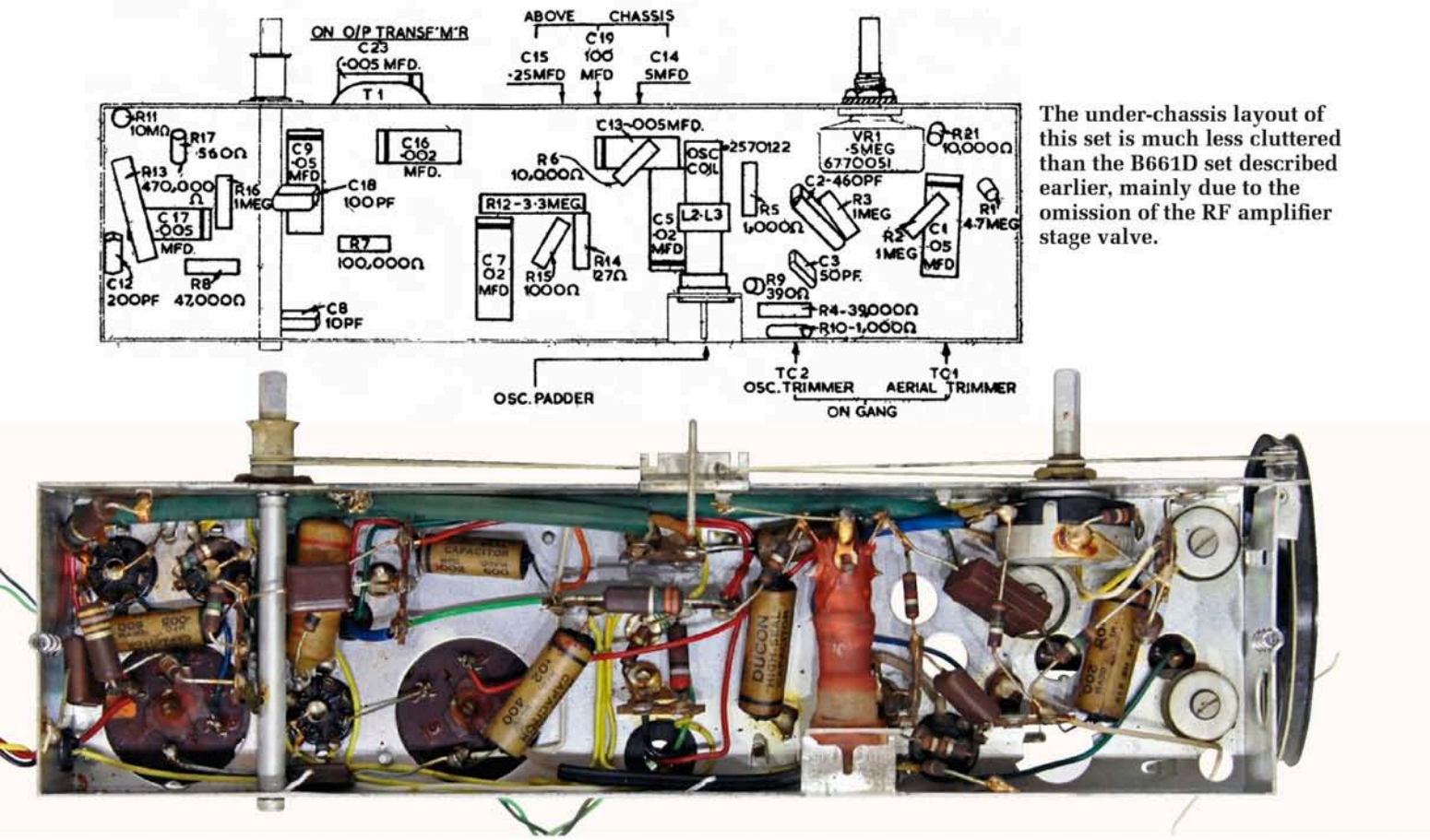
"Although the time of reactivation is not critical within an hour or so, it is important not to exceed the recommended period by any considerable margin. The ratio of reactivation to battery usage time applies only to the last daily period used."

"For example should the receiver be used on batteries for a total of two hours daily for three days without reactivating, then the reactivating period would be twelve hours, based on the last period of two hours usage."

"The cost of power taken from the electric supply mains for reactivation is very low. On the basis of power costing 3d [three pennies] per unit, the cost of a reactivating charge of twelve hours would be approximately one third of a penny."

While HMV referred to it as reactivation, this shows that charging of carbon-zinc batteries has been around for more than 60 years, even though battery manufacturers normally do not recommend charging of any primary batteries.

Reversing the chemical reaction that creates battery current is a simple matter of chemistry, but the advisability of doing so is another matter. During reactivation, there would also be elec-



The under-chassis layout of this set is much less cluttered than the B661D set described earlier, mainly due to the omission of the RF amplifier stage valve.

Just for reference, here is what the set looked like pre-restoration. You can see the dial is slightly cracked along the Queensland section.

trolysis of the aqueous electrolyte releasing hydrogen gas.

Reactivation does not create a magic pudding of inexhaustible power because the chemistry is not completely reversed.

Modern alkaline batteries can likewise be regenerated, through perhaps ten cycles, and there are many commercial products to do this. See the discussion at https://en.wikipedia.org/wiki/Recharging_alkaline_batteries

The speaker

The 1951 model previously described had a round 5-inch speaker that was labelled HMV. This 1955 model has a larger 5x7-inch elliptical speaker branded EMI and this would have been manufactured at the Homebush plant in Sydney.

The HMV brand was first used by the Gramophone Company UK in London in 1921 for gramophones and records. In 1931, The Gramophone Company and The Columbia Company merged to form Electric and Musical Industries (EMI) and began manufacturing radios. HMV radios were made in Australia from 1936 at Homebush.

From the mid-1950s onward, all HMV radios, valve and transistor, carried an EMI logo on the speakers. The HMV radios of the time were also badge-engineered as Kelvinator with some modified case work. Using EMI as the speaker brand disguised its origin at HMV.

AWA did the same thing when it branded speakers MSP (Manufacturers Special Products) so that other manufacturers would not be overtly conflicted when they used MSP speakers.

A view of the case from the back shows the elliptical space for mounting the speaker. A picture of the rear of the case also shows the slots that guide the chassis to precisely register the knobs with their access ports.

A bonus with this radio is the internally pencilled signature ("ER"), presumably of the person who checked this radio for dispatch.

The dial background is red, a change from the dark brown of earlier models.

The previously described 1951 model B61D had a cluttered, tightly-packed arrangement of components under the chassis. This radio is much less cramped, partly because it lacks an RF amplifier section. Also, the bulky power filter capacitors are mounted on the chassis, not below.

This model also incorporates more modern compact components, notably the resistors that have the now-familiar colour bands for indicating values.

Although this radio lacks an RF amplifier section, other HMV models such as the 22-11 of 1956 offered both an RF amplifier and a mains power unit.

Restoration

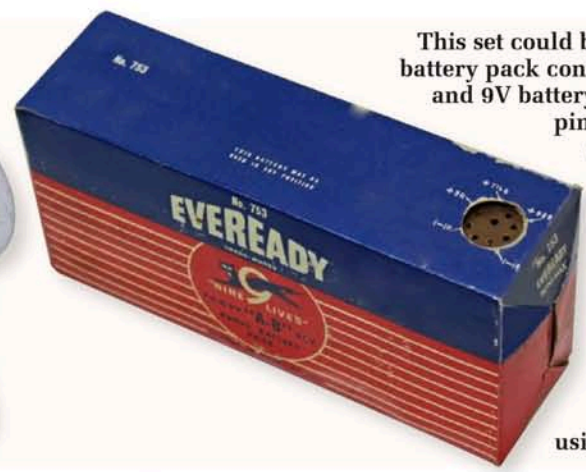
This radio was a relatively easy restoration project. However, at first power-up, it remained absolutely silent. The solution was meticulous cleaning of all valve pins and sockets to ensure reliable contact.

During handling, the celluloid dial sadly cracked and disintegrated into fragments. Happily, a reproduction dial was at hand, printed as described in the article on the B61D, June 2017.

This radio was one of nine HMV portables restored as a batch. Some were more challenging than this radio and their story may be told later.

This radio is a reasonable performer on local stations in my area of good signal strength. The case polished up well so this restoration had a pleasing conclusion. SC

The HMV 12-11 uses a 5x7-inch elliptical speaker. This speaker sports the EMI label, which was not present on the speaker in the B61D four years earlier.



This set could be powered by a battery pack containing one 90V and 9V battery, using a multi-pin connector. The disadvantage of this is that the pack would need to be discarded as soon as one of the two batteries became flat. This could be mitigated by using reactivation.

SILICON CHIP .com.au/shop ONLINESHOP

Looking for a specialised component to build that latest and greatest *Silicon Chip* project? Maybe it's the PCB you're after? Or a pre-programmed micro? Or some other hard-to-get "bit"? The chances are they are available direct from the *Silicon Chip* ONLINESHOP.

As a service to readers, *Silicon Chip* has established the ONLINESHOP. No, we're not going into opposition with your normal suppliers – this is a direct response to requests from readers who have found difficulty in obtaining specialised parts such as PCBs & micros.

- PCBs are normally IN STOCK and ready for despatch when that month's magazine goes on sale (you don't have to wait for them to be made!).
- Even if stock runs out (eg, for high demand), in most cases there will be no longer than a two-week wait.
- One low p&p charge: $10 per order, regardless of how many boards or micros you order! (Australia only; overseas clients – email us for a postage quote).
- Our PCBs are beautifully made, very high quality fibreglass boards with pre-tinned tracks, silk screen overlays and where applicable, solder masks.
- Best of all, those boards with fancy cut-outs or edges are already cut out to the *SILICON CHIP* specifications – no messy blade work required!

HERE'S HOW TO ORDER:

VISA MasterCard PayPal

All prices are in AUSTRALIAN DOLLARS ($AU)

✔ **Via the INTERNET** (24 hours, 7 days): Log on to our secure website – siliconchip.com.au, click on "SHOP" and follow the links

✔ **Via EMAIL** (24 hours, 7 days): email silicon@siliconchip.com.au – Clearly tell us what you want and include your contact and credit card details

✔ **Via MAIL** (24 hours, 7 days): PO Box 139, Collaroy NSW 2097. Clearly tell us what you want and include your contact and credit card details

✔ **Via PHONE** (9am-5pm EADST, Mon-Fri): Call (02) 9939 3295 (INT 612 9939 3295) – have your order ready, including contact and credit card details!

YES! You can also order or renew your SILICON CHIP subscription via any of these methods as well!

PRE-PROGRAMMED MICROS

Price for any of these micros is just $15.00 each + $10 p&p per order#

As a service to readers, *Silicon Chip OnLineShop* stocks microcontrollers and microprocessors *used in new projects* (from 2012 on) and some selected older projects – pre-programmed and ready to fly!

Some micros from copyrighted and/or contributed projects may not be available.

PIC12F675-I/P	UHF Remote Switch (Jan09), Ultrasonic Cleaner (Aug10), Ultrasonic Anti-fouling (Sep10), Cricket/Frog (Jun12), Do Not Disturb (May13) IR-to-UHF Converter (Jul13), UHF-to-IR Converter (Jul13) PC Birdies *2 chips – $15 pair* (Aug13), Driveway Monitor Receiver (July15) Hotel Safe Alarm (Jun16), 50A Battery Charger Controller (Nov16) **Kelvin the Cricket (Oct17)**
PIC16F1455-I/P	Microbridge (May17)
PIC16F1507-I/P	Wideband Oxygen Sensor (Jun-Jul12)
PIC16F88-E/P	Hi Energy Ignition (Nov/Dec12), Speedo Corrector (Sept13), Auto Headlight Controller (Oct13), 10A 230V Motor Speed Controller (Feb14) Automotive Sensor Modifier (Dec16)
PIC16F88-I/P	Projector Speed (Apr11), Vox (Jun11), Ultrasonic Water Tank Level (Sep11) Quizzical (Oct11), Ultra LD Preamp (Nov11), 10-Channel Remote Control Receiver (Jun13), Revised 10-Channel Remote Control Receiver (Jul13) Nicad/NiMH Burp Charger (Mar14), Remote Mains Timer (Nov14) Driveway Monitor Transmitter (July15), Fingerprint Scanner (Nov15) MPPT Lighting Charge Controller (Feb16), 50/60Hz Turntable Driver (May16) Cyclic Pump Timer (Sep16), 60V 40A DC Motor Speed Controller (Jan17) Pool Lap Counter (Mar17), Rapidbrake (Jul17)
PIC16LF88-I/P	Garbage Reminder (Jan13), Bellbird (Dec13), GPS Analog Clock Driver (Feb17)
PIC16LF88-I/SO	LED Ladybird (Apr13)
PIC16LF1709-I/SO	Battery Cell Balancer (Mar16)
PIC16F877A-I/P	6-Digit GPS Clock (May-Jun09), Lab Digital Pot (Jul10), Semtest (Feb-May12)
PIC16F2550-I/SP	Batt Capacity Meter (Jun09), Intelligent Fan Controller (Jul10)
PIC18F4550-I/P	GPS Car Computer (Jan10), GPS Boat Computer (Oct10)
PIC32MX795F512H-80I/PT	Maximite (Mar11), miniMaximite (Nov11), Colour Maximite (Sept/Oct12) Touchscreen Audio Recorder (Jun/Jul 14)
PIC32MX170F256B-50I/SP	Micromite Mk2 (Jan15) – *also includes* ***FREE*** *47µF tantalum capacitor* Micromite LCD BackPack [either version] (Feb16), GPS Boat Computer (Apr16) Micromite Super Clock (Jul16), Touchscreen Voltage/Current Ref (Oct-Dec16) Micromite LCD BackPack V2 (May17), Deluxe eFuse (Aug17) Micromite DDS for IF Alignment (Sept17)
PIC32MX170F256B-I/SP	Low Frequency Distortion Analyser (Apr15)
PIC32MX170F256D-501P/T	44-pin Micromite Mk2 (Now with Mk2 Firmware at no extra cost)
PIC32MX250F128B-I/SP	GPS Tracker (Nov13), Micromite ASCII Video Terminal (Jul14)
PIC32MX470F512H-I/PT	Stereo Audio Delay/DSP (Nov13), Stereo Echo/Reverb (Feb 14) Digital Effects Unit (Oct14)
PIC32MX470F512H-120/PT	Micromite PLUS Explore 64 (Aug 16), Micromite Plus LCD BackPack (Nov16)
PIC32MX470F512L-120/PT	Micromite PLUS Explore 100 (Sep-Oct16)
dsPIC33FJ128GP802-I/SP	Digital Audio Signal Generator (Mar-May10), Digital Lighting Controller (Oct-Dec10), SportSync (May11), Digital Audio Delay (Dec11) Quizzical (Oct11), Ultra-LD Preamp (Nov11), LED Musicolor (Nov12)
dsPIC33FJ64MC802-E/P	Induction Motor Speed Controller (revised) (Aug13)
dsPIC33FJ128GP306-I/PT	CLASSiC DAC (Feb-May 13)
ATTiny861	Thermometer/Thermostat (Mar10), Rudder Position Indicator (Jul11)
ATTiny2313	Remote-Controlled Timer (Aug10)

When ordering, be sure to nominate BOTH the micro required AND the project for which it must be programmed.

SPECIALISED COMPONENTS, HARD-TO-GET BITS, ETC

P&P – $10 Per order#

NEW THIS MONTH:

PARTS FOR THE 6GHz+ TOUCHSCREEN FREQUENCY COUNTER *(OCT 17)*
Explore 100 kit (Cat SC3834; no LCD included) **$69.90**
one ERA-2SM+ & one ADCH-80A+ (Cat SC1167; two packs required) **$15.00/pack**

3-WAY ADJUSTABLE ACTIVE CROSSOVER *(SEPT 17)*
- set of laser-cut black acrylic case pieces **$10.00**

LOGGING DATA TO THE 'NET USING ARDUINO *(SEPT 17)*
- WeMos D1 R2 board **$12.50**

DELUXE EFUSE PARTS *(AUG 17)*
IPP80P03P4L04 P-channel mosfets **$4.00 ea**
BUK7909-75AIE 75V 120A N-channel SenseFet **$7.50 ea**
LT1490ACN8 dual op amp **$7.50 ea**

ARDUINO MUSIC PLAYER/RECORDER *(JUL 17)*
Geeetech Arduino MP3 shield **$20.00**

ARDUINO LC METER *(JUN 17)*
1nF 1% MKP capacitor, 5mm lead spacing **$2.50**

MAX7219 LED DISPLAY MODULES *(JUN 17)*
8x8 LED matrix module with **DIP** MAX7219 **$5.00**
8x8 LED matrix module with **SMD** MAX7219 **$5.00**
8-digit 7-segment red display module with **SMD** MAX7219 **$7.50**

MICROBRIDGE *(MAY 17)*
PCB plus all on-board parts including programmed microcontroller (SMD ceramics for 10µF) **$20.00**

MICROMITE LCD BACKPACK V2 – COMPLETE KIT *(MAY 17)*
includes PCB, programmed micro, touchscreen LCD, laser-cut UB3 lid, mounting hardware, SMD Mosfets for PWM backlight control and all other on-board parts **$70.00**

EFUSE *(APR 17)*
two NIS5512 ICs plus one SUP53P06 **$22.50**

DDS MODULES *(APR 17)*
AD9833 DDS module (with gain control) (for Micromite DDS) **$25.00**
AD9833 DDS module (no gain control) (El Cheapo Modules, Part 6) **$15.00**

POOL LAP COUNTER *(MAR 17)*
two 70mm 7-segment high brightness blue displays plus logic-level Mosfet **$17.50**
laser-cut blue tinted lid, 152 x 90 x 3mm **$7.50**

STATIONMASTER *(MAR 17)*
DRV8871 IC, SMD 1µF capacitor and 100kW potentiometer with detent **$12.50**

ULTRA LOW VOLTAGE LED FLASHER *(FEB 17)*
kit including PCB and all SMD parts, LDR and blue LED **$12.50**

SC200 AMPLIFIER MODULE *(JAN 17)* **$35.00**
hard-to-get parts: Q8-Q16, D2-D4, 150pF/250V capacitor and five SMD resistors

60V 40A DC MOTOR SPEED CONTROLLER *(JAN 17)* **$35.00**
hard-to-get parts: IC2, Q1, Q2 and D1

COMPUTER INTERFACE MODULES *(JAN 17)*
CP2102 USB-UART bridge **$5.00**
microSD card adaptor **$2.50**

TOUCHSCREEN VOLTAGE/CURRENT REFERENCE *(DEC 16)*
MICROMITE LCD BACKPACK KIT (programmed to suit) PLUS UB1 Lid **$70.00**
LASER-CUT MATTE BLACK LID (to suit UB1 Jiffy Box) **$10.00**
SHORT FORM KIT with main PCB plus onboard parts (not including BackPack module, jiffy box, power supply or wires/cables) **$99.00**

PASSIVE LINE TO PHONO INPUT CONVERTER - ALL SMD PARTS *(NOV 16)* **$5.00**

MICROMITE PLUS EXPLORE 100 ***COMPLETE KIT (no LCD panel)*** *(SEP 16)* **$69.90**
(includes PCB, programmed micro and the hard-to-get bits including female headers, USB and microSD sockets, crystal, etc but does not include the LCD panel)

THESE ARE ONLY THE MOST RECENT MICROS AND SPECIALISED COMPONENTS. FOR THE FULL LIST, SEE www.siliconchip.com.au/shop

*All items subect to availability. Prices valid for month of magazine issue only. All prices in Australian dollars and included GST where applicable. **# P&P prices are within Australia. O'seas? Please email for a quote**

PRINTED CIRCUIT BOARDS

NOTE: The listings below are for the PCB only – *not a full kit*. If you want a kit, contact the kit suppliers advertising in this issue. For more unusual projects where kits are not available, some have specialised components available – see the list opposite.

NOTE: Not all PCBs are shown here due to space limits but the SILICON CHIP ONLINESHOP has boards going back to 2001 and beyond. For a complete list of available PCBs, back issues, etc, go to *siliconchip.com.au/shop* Prices are PCBs only, NOT COMPLETE KITS!

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
CLASSIC-D CLASS D AMPLIFIER MODULE	NOV 2012	01108121	$30.00
CLASSIC-D 2 CHANNEL SPEAKER PROTECTOR	NOV 2012	01108122	$10.00
HIGH ENERGY ELECTRONIC IGNITION SYSTEM	DEC 2012	05110121	$10.00
1.5kW INDUCTION MOTOR SPEED CONTROLLER (NEW V2 PCB)	DEC 2012	10105122	$35.00
THE CHAMPION PREAMP and 7W AUDIO AMP (one PCB)	JAN 2013	01109121/2	$10.00
2.5GHz DIGITAL FREQUENCY METER – MAIN BOARD	JAN 2013	04111121	$35.00
2.5GHz DIGITAL FREQUENCY METER – DISPLAY BOARD	JAN 2013	04111122	$15.00
2.5GHz DIGITAL FREQUENCY METER – FRONT PANEL	JAN 2013	04111123	$45.00
SEISMOGRAPH MK2	FEB 2013	21102131	$20.00
MOBILE PHONE RING EXTENDER	FEB 2013	12110121	$10.00
GPS 1PPS TIMEBASE	FEB 2013	04103131	$10.00
LED TORCH DRIVER	MAR 2013	16102131	$5.00
CLASSiC DAC MAIN PCB	APR 2013	01102131	$40.00
CLASSIC DAC FRONT & REAR PANEL PCBs	APR 2013	01102132/3	$30.00
GPS USB TIMEBASE	APR 2013	04104131	$15.00
LED LADYBIRD	APR 2013	08103131	$5.00
CLASSiC-D 12V to ±35V DC/DC CONVERTER	MAY 2013	11104131	$15.00
DO NOT DISTURB	MAY 2013	12104131	$10.00
LF/HF UP-CONVERTER	JUN 2013	07106131	$10.00
10-CHANNEL REMOTE CONTROL RECEIVER	JUN 2013	15106131	$15.00
IR-TO-455MHz UHF TRANSCEIVER	JUN 2013	15106132	$7.50
"LUMP IN COAX" PORTABLE MIXER	JUN 2013	01106131	$15.00
L'IL PULSER MKII TRAIN CONTROLLER	JULY 2013	09107131	$15.00
L'IL PULSER MKII FRONT & REAR PANELS	JULY 2013	09107132/3	$20.00/set
REVISED 10 CHANNEL REMOTE CONTROL RECEIVER	JULY 2013	15106133	$15.00
INFRARED TO UHF CONVERTER	JULY 2013	15107131	$5.00
UHF TO INFRARED CONVERTER	JULY 2013	15107132	$10.00
IPOD CHARGER	AUG 2013	14108131	$5.00
PC BIRDIES	AUG 2013	08104131	$10.00
RF DETECTOR PROBE FOR DMMs	AUG 2013	04107131	$10.00
BATTERY LIFESAVER	SEPT 2013	11108131	$5.00
SPEEDO CORRECTOR	SEPT 2013	05109131	$10.00
SiDRADIO (INTEGRATED SDR) Main PCB	OCT 2013	06109131	$35.00
SiDRADIO (INTEGRATED SDR) Front & Rear Panels	OCT 2013	06109132/3	$25.00/pr
TINY TIM AMPLIFIER (same PCB as Headphone Amp [Sept11])	OCT 2013	01309111	$20.00
AUTO CAR HEADLIGHT CONTROLLER	OCT 2013	03111131	$10.00
GPS TRACKER	NOV 2013	05112131	$15.00
STEREO AUDIO DELAY/DSP	NOV 2013	01110131	$15.00
BELLBIRD	DEC 2013	08112131	$10.00
PORTAPAL-D MAIN BOARDS	DEC 2013	01111131-3	$35.00/set
(for CLASSiC-D Amp board and CLASSiC-D DC/DC Converter board refer above [Nov 2012/May 2013])			
LED Party Strobe (also suits Hot Wire Cutter [Dec 2010])	JAN 2014	16101141	$7.50
Bass Extender Mk2	JAN 2014	01112131	$15.00
Li'l Pulser Mk2 Revised	JAN 2014	09107134	$15.00
10A 230VAC MOTOR SPEED CONTROLLER	FEB 2014	10102141	$12.50
NICAD/NIMH BURP CHARGER	MAR 2014	14103141	$15.00
RUBIDIUM FREQ. STANDARD BREAKOUT BOARD	APR 2014	04105141	$10.00
USB/RS232C ADAPTOR	APR 2014	07103141	$5.00
MAINS FAN SPEED CONTROLLER	MAY 2014	10104141	$10.00
RGB LED STRIP DRIVER	MAY 2014	16105141	$10.00
HYBRID BENCH SUPPLY	MAY 2014	18104141	$20.00
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	JUN 2014	01205141	$20.00
TOUCHSCREEN AUDIO RECORDER	JUL 2014	01105141	$12.50
THRESHOLD VOLTAGE SWITCH	JUL 2014	99106141	$10.00
MICROMITE ASCII VIDEO TERMINAL	JUL 2014	24107141	$7.50
FREQUENCY COUNTER ADD-ON	JUL 2014	04105141a/b	$15.00
TEMPMASTER MK3	AUG 2014	21108141	$15.00
44-PIN MICROMITE	AUG 2014	24108141	$5.00
OPTO-THEREMIN MAIN BOARD	SEP 2014	23108141	$15.00
OPTO-THEREMIN PROXIMITY SENSOR BOARD	SEP 2014	23108142	$5.00
ACTIVE DIFFERENTIAL PROBE BOARDS	SEP 2014	04107141/2	$10/SET
MINI-D AMPLIFIER	SEP 2014	01110141	$5.00
COURTESY LIGHT DELAY	OCT 2014	05109141	$7.50
DIRECT INJECTION (D-I) BOX	OCT 2014	23109141	$5.00
DIGITAL EFFECTS UNIT	OCT 2014	01110131	$15.00
DUAL PHANTOM POWER SUPPLY	NOV 2014	18112141	$10.00
REMOTE MAINS TIMER	NOV 2014	19112141	$10.00
REMOTE MAINS TIMER PANEL/LID (BLUE)	NOV 2014	19112142	$15.00
ONE-CHIP AMPLIFIER	NOV 2014	01109141	$5.00
TDR DONGLE	DEC 2014	04112141	$5.00
MULTISPARK CDI FOR PERFORMANCE VEHICLES	DEC 2014	05112141	$10.00
CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD	DEC 2014	01111141	$50.00
CURRAWONG REMOTE CONTROL BOARD	DEC 2014	01111144	$5.00
CURRAWONG FRONT & REAR PANELS	DEC 2014	01111142/3	$30/set
CURRAWONG CLEAR ACRYLIC COVER	JAN 2015	-	$25.00
ISOLATED HIGH VOLTAGE PROBE	JAN 2015	04108141	$10.00
SPARK ENERGY METER MAIN BOARD	FEB/MAR 2015	05101151	$10.00
SPARK ENERGY ZENER BOARD	FEB/MAR 2015	05101152	$10.00
SPARK ENERGY METER CALIBRATOR BOARD	FEB/MAR 2015	05101153	$5.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
LOW-FREQUENCY DISTORTION ANALYSER	APR 2015	04104151	$5.00

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
BALANCED INPUT ATTENUATOR MAIN PCB	MAY 2015	04105151	$15.00
BALANCED INPUT ATTENUATOR FRONT & REAR PANELS	MAY 2015	04105152/3	$20.00
4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$2.50
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$5.00
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109121/2	$7.50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	JULY 2015	18107151	$2.50
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
9-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	1510815	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$2.50
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/2	$15.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19110151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101161	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SPEEDUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16101161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50
BATTERY CELL BALANCER	MAR 2016	11111151	$6.00
DELTA THROTTLE TIMER	MAR 2016	05102161	$15.00
MICROWAVE LEAKAGE DETECTOR	APR 2016	04103161	$5.00
FRIDGE/FREEZER ALARM	APR 2016	03104161	$5.00
ARDUINO MULTIFUNCTION MEASUREMENT	APR 2016	04116011/2	$15.00
PRECISION 50/60Hz TURNTABLE DRIVER	MAY 2016	04104161	$15.00
RASPBERRY PI TEMP SENSOR EXPANSION	MAY 2016	24104161	$5.00
100DB STEREO AUDIO LEVEL/VU METER	JUN 2016	01104161	$15.00
HOTEL SAFE ALARM	JUN 2016	03106161	$5.00
UNIVERSAL TEMPERATURE ALARM	JULY 2016	03105161	$5.00
BROWNOUT PROTECTOR MK2	JULY 2016	10107161	$10.00
8-DIGIT FREQUENCY METER	AUG 2016	04105161	$10.00
APPLIANCE ENERGY METER	AUG 2016	04116061	$15.00
MICROMITE PLUS EXPLORE 64	AUG 2016	07108161	$5.00
CYCLIC PUMP/MAINS TIMER	SEPT 2016	10108161/2	$10.00/pair
MICROMITE PLUS EXPLORE 100 (4 layer)	SEPT 2016	07109161	$20.00
AUTOMOTIVE FAULT DETECTOR	SEPT 2016	05109161	$10.00
MOSQUITO LURE	OCT 2016	25110161	$5.00
MICROPOWER LED FLASHER	OCT 2016	16109161	$5.00
MINI MICROPOWER LED FLASHER	OCT 2016	16109162	$2.50
50A BATTERY CHARGER CONTROLLER	NOV 2016	11111161	$10.00
PASSIVE LINE TO PHONO INPUT CONVERTER	NOV 2016	01111161	$5.00
MICROMITE PLUS LCD BACKPACK	NOV 2016	07110161	$7.50
AUTOMOTIVE SENSOR MODIFIER	DEC 2016	05111161	$10.00
TOUCHSCREEN VOLTAGE/CURRENT REFERENCE	DEC 2016	04110161	$12.50
SC200 AMPLIFIER MODULE	JAN 2017	01108161	$10.00
60V 40A DC MOTOR SPEED CON. CONTROL BOARD	JAN 2017	11112161	$10.00
60V 40A DC MOTOR SPEED CON. MOSFET BOARD	JAN 2017	11112162	$12.50
GPS SYNCHRONISED ANALOG CLOCK	FEB 2017	04202171	$10.00
ULTRA LOW VOLTAGE LED FLASHER	FEB 2017	16110161	$2.50
POOL LAP COUNTER	MAR 2017	19102171	$15.00
STATIONMASTER TRAIN CONTROLLER	MAR 2017	09103171/2	$15.00/set
EFUSE	APR 2017	04102171	$7.50
SPRING REVERB	APR 2017	01104171	$12.50
6GHz+ 1000:1 PRESCALER	MAY 2017	04112162	$7.50
MICROBRIDGE	MAY 2017	24104171	$2.50
MICROMITE LCD BACKPACK V2	MAY 2017	07104171	$7.50
10-OCTAVE STEREO GRAPHIC EQUALISER PCB	JUN 2017	01105171	$12.50
10-OCTAVE STEREO GRAPHIC EQUALISER FRONT PANEL	JUN 2017	01105172	$15.00
10-OCTAVE STEREO GRAPHIC EQUALISER CASE PIECES	JUN 2017		$15.00
RAPIDBRAKE	JUL 2017	05105171	$10.00
DELUXE EFUSE	AUG 2017	18106171	$15.00
DELUXE EFUSE UB1 LID	AUG 2017	SC4316	$5.00
MAINS SUPPLY FOR BATTERY VALVES (INC. PANELS)	AUG 2017	18108171-4	$25.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER	SEPT 2017	01108171	$20.00
3-WAY ADJUSTABLE ACTIVE CROSSOVER PANELS	SEPT 2017	01108172/3	$20.00/pair
NEW THIS MONTH			
6GHz+ TOUCHSCREEN FREQUENCY COUNTER	OCT 2017	04110171	$10.00
KELVIN THE CRICKET	OCT 2017	08109171	$10.00

LOOKING FOR TECHNICAL BOOKS? YOU'LL FIND THE COMPLETE LISTING OF ALL BOOKS AVAILABLE IN THE SILKS & DVDs" PAGES AT SILICONCHIP.COM.AU/SHOP

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Swishing noises from DAB+/FM stereo tuner

This is a follow up to my recent email and your reply about the DAB+/FM tuner (SILICON CHIP, October, November & December 2010) and "swishing" artefacts in the audio output.

I tested the tuner using the S/PDIF optical output into an external DAC. The audio artefacts were still present. This rules out the built-in DAC in the Venice 7 module as the cause.

This leaves the FM demodulation section of the Venice 7 module as the probable source. The fact that the artefacts occur only when decoding an FM stereo signal lends weight to this idea.

The artefacts are not present when the tuner is in "mono" mode (eg, for a brief period after changing stations). This suggests that they are being generated by the stereo demodulation hardware/software.

I find it hard to believe that this very specific behaviour would be limited only to a single Venice 7 module or that it could be caused by faulty soldering – something which I re-checked in any case. You mentioned that you "had never had a complaint from any other reader along those lines".

Perhaps other readers were primarily interested in receiving DAB+ broadcasts and did not pay a lot of attention to the FM stereo performance? Perhaps the "swishing" artefacts are simply not objectionable enough for them to bother reporting? I find them noticeable only in quiet sections of classical music.

Frontier Silicon, the makers of the Venice 7 module, are primarily focussed on digital radio. Online press releases and articles about the Venice 7 module from around the time of its release emphasise its use for the new medium of digital radio – in particular in portable devices and in cars – situations where one might expect a fair amount of ambient background noise.

Receiving conventional FM broadcasts might have been regarded as a "nice thing to have" for backward compatibility but may not have been the primary design goal, nor their primary market. Perhaps they accepted less-than-ideal FM stereo performance, reasoning that their target market was not the hifi market?

Anyway, I'm not too fussed. I will try to find a good home for this tuner with someone who wants to receive DAB+ radio. We live in a rural area and there are no digital radio broadcasts (please let me know if you know anyone who would like it).

In the mean time we can listen to ABC Classic FM streamed over the internet – arguably a cleaner and less noisy version than FM. (P. H., via email)

● You are right in that Frontier Silicon do appear to be more focussed on portable and car applications where ambient noise can be quite high. We can also confirm that the stereo quieting performance (-60dB) of the Venice tuner module (in the spec panel on page 25 of the October 2010 issue) is not as good as the best Japanese FM tuners of the past. However, in our judgement, the FM quieting performance was adequate.

Limiting hot water power to suit solar system

I was looking at using my excess photovoltaic power to heat my hot water. The problem is that the element is 3.6kW and hence it consumes more power than I have in excess from the PV system in winter.

I was thinking about introducing a circuit that dropped cycles (ie, switched at the zero crossings) and then came across the February-March 2014 10A/230V Universal Motor Speed Controller (www.siliconchip.com.au/Series/195).

Maybe I could use this to limit the power consumed by the hot water heater. I want it to be adjustable in the range of 0-2kW. Would it be suitable?

● We have answered questions on this topic before and one suggestion has been to feed DC from the solar panel array directly to the tank heater (ie, bypassing the grid-tied inverter).

That would require separate AC contactors to isolate the tank heater from the mains supply and to connect the high voltage DC from the solar panels to the tank and that would be a job for a licensed electrician. We doubt whether most electricians who are approved solar installers would agree to do it.

Your suggestion to use the speed controller circuit from February/March 2014 is interesting. Ostensibly, the 35A bridge rectifier and the IGBT could handle the peak currents of more than 20A.

However, we don't know how you would determine how much spare power you had, in order to adjust the water heater power to suit. You might end up drawing significant power from the grid as a result.

Where a Smart Meter is installed, the "controlled off-peak" and "off-peak" tariffs are much lower than the "shoulder" tariff, so you would want to avoid even partially feeding grid power to the hot-water system during the day when the "shoulder" or peak tariffs would apply.

Also, you would need a contactor to isolate the tank heater from the "controlled off-peak" circuit from your Smart Meter when using the speed controller with it, and that would also be a job for a licensed electrician.

On balance, we would strongly recommend not using that method.

We agree that any swishing noises on FM stereo performance would probably only be noticeable on quiet passages of classical music.

However, we would be surprised if the swishing noise is an artefact of the stereo demodulation hardware/software, although that is a possibility. We did not notice this problem on the prototype when we did our quieting and listening tests.

Possibly another constructor has observed the same fault and they may have happened on a cure.

By the way, there are plans to extend DAB+ broadcasts into regional areas within the next few years although we don't know whether they will actually be implemented.

Mystified by rotating sails

I was intrigued by the story on ships with rotating sails, in the June 2017 issue (www.siliconchip.com.au/Article/10672). How do the rotating sails actually help with thrust and forward movement of the ship that these sails are fitted to? Are there shafts inside the rotating sails, connected via gearboxes to the ship's propellers? Otherwise, how does the ship gain forward thrust and movement from these sails?

● The three diagrams on pages 12 & 13 explain how the Magnus force is developed. The rotating shafts are just like a sail – they experience thrust which moves the ship forward. There is no need for any shaft coupling between the rotating sails and the propellers.

May the (Magnus) Force be with you.

Class-A Amplifier gazumped

I learned last week that Altronics is no longer stocking your 20W Stereo Class A amplifier (May-September 2007; www.siliconchip.com.au/Series/58) as a kit. Is this amplifier under revision and if so, do you have an expected publication timeframe? Or if the amplifier is not being revised, please just let me know as I think I will build it from scratch. (G. B., Wamboin, NSW)

● We aren't planning on publishing any new Class-A amplifiers in the near future. Our Ultra-LD series of amplifiers provide similar performance with much higher maximum power and efficiency and at only a slightly higher cost.

If you still want a Class-A amplifier, the 20W design from 2007 is still valid and you should not have any trouble building one. We are now supplying PCBs for this project for those who still want to build it and can't get a kit. They are available at www.siliconchip.com.au/Shop/?article=2341

The other parts should not be difficult to acquire although we haven't checked them all individually.

Band 3 TV Yagi antenna design wanted

In the past I have asked for a band 3 television Yagi antenna project, only to be told that it is not economically worthwhile. Since then, SILICON CHIP has published a five-element DAB+ antenna project (November 2015; www.siliconchip.com.au/Article/9394) and I suspect if this is used on a horizontal plane, it may give good service as a television antenna!

I suspect that many readers of SILICON CHIP are quite happy to roll their own antennas and also recycle their old antennas. There is enough aluminium in the old analog channel 2 directors/reflectors alone to make all the directors in a modern band 3 Yagi. So could you please publish at least the critical dimensions for a five- or six-element band 3 (174-230MHz) Yagi? (A. P., North Sunshine, Vic)

● This is a good suggestion. Now that the digital TV bands have been restacked, it makes sense to have a look at a five- or six-element Yagi for VHF TV reception. In broad terms, the DAB+ antenna would need to be scaled up in size to suit those particular bands. However, the DAB+ band is smack in the centre of the two designated VHF TV bands and so in many areas, you could probably use the DAB+ antenna with good results.

We will consider doing this project and while it is not particularly cheap if you use all-new aluminium stock, many readers may decide to recycle old TV antennas.

Oscar inoperative due to dud switch

I purchased a microcontroller from the SILICON CHIP on-line shop recently, to make the Oscar project (October 2007; www.siliconchip.com.au/Article/2391).

Was the chip already programmed or do I have to program it? The reason I ask is that I followed the fault-finding instructions in the article and all the functions work without the chip installed.

The article states if the fault-finding procedure is OK, then the chip is not programmed or faulty. I did not notice any marking on the chip to indicate it was programmed. What advice can you give me please? (T. C., via email)

● The chip is programmed; we don't mark chips that are programmed but since we don't sell blank chips, it's highly likely that the one you received has been programmed. If you have done the fault-finding checks, it

Pain in the BackPack

I purchased the complete Micromite LCD BackPack kit with touchscreen LCD from your online shop. Does the microcontroller come preprogrammed?

I cannot get the display to light up. The UART LEDs flash after each key press on the PC via USB and all test voltages appear correct. (M. L., Landsdale, WA)

● Yes, the chips supplied are programmed. The display should light up regardless, though, because you purchased the BackPack V2 kit (www.siliconchip.com.au/Shop/20/4237) and with that design, the backlight is biased on by default.

If the backlight is not coming on, that suggests one of the following problems:

1. Q1, Q2 or one of the two associated resistors are not properly soldered.
2. the LCD module has not been plugged in correctly or is faulty.

Please check the voltage between the LED anode pin on CON3 and ground. The pins are not numbered but if V_{CC} (5V) is pin 1 and GND is pin 2 then the LED anode will be pin 8.

You should have 5V between pin 8 and pin 2. Otherwise, there is something wrong with the Mosfets.

is possible that the circuit is not working because not all pins of the micro have made proper contact or you may have one of more of the switches open-circuit. (Editor's note: we have since been advised that one of the switches was faulty).

Difficulty in installing fan/light timer

I refer to the August 2012 publication of SILICON CHIP that had the project on Mains Timer for a Fan/Light. (www.siliconchip.com.au/Article/577).

I bought the kit (Jaycar KC5512) quite some time back but did not get around to assembling it. However, based on the circuit diagrams provided, I find it impossible to retrofit the timer into an existing wiring for a bathroom fan/light.

The reason is that the switch is usually on the bathroom wall or door jamb. It is not possible to isolate the Mains Active wire and take it to the Timer terminal.

I have had my electrician check this out and because I have a 2-storey house the Active is taken to the wall switch and only the switch side, along with Neutral, is wired to the fan/ light in the roof space. This will require rewiring the existing system to achieve the result. Your thoughts are welcome. (S. W., via email)

● This is a little tricky but your electrician should be able to manage it. He will need to run an Active wire from the wall or architrave switch up through wall space to connect it to the fan timer. It is really a two-person job but quite routine. The only reason why it might not be possible is if the switch wiring has been "chased" into a rendered wall instead of being run in conduit.

Increasing Studio 350 power supply voltage

I'm thinking of building a second pair of the Studio 350 power ampifiers (January & February 2004; www.siliconchip.com.au/Series/97).

I am already using a pair to power the bass drivers in an active-crossover based tri-amplified stereo system. The power transformer I have available will provide ±75V DC rails (measured) which is slightly higher than the ±70V recommended.

Will the amps handle this slightly higher supply? There isn't a lot of variation in the 230VAC mains supply where these will be used. (J. McC., Auckland, NZ)

● A check of the load lines on page 14 of the January 2004 article shows that 75V rails will be OK with this amplifier.

Controlling a passive roof fan

I would like to make a comment regarding the discussion of a possible Solar pool pump/chlorinator/water heater controller, in the Mailbag section of the June 2017 issue (page 5; www.siliconchip.com.au/Article/10667). You could also use it to control a roof fan to extract hot air from roof space on hot days.

Instead of using an electric fan, what about a solenoid or small electric motor with gearbox from Jaycar, to stop (or not) a "whirligig" type wind-powered roof extraction fan? These are used to extract hot air from the roof space on hot days and use wind power instead of now-expensive electricity to power the fan.

From memory, Bunnings carry a fan of this type which is not expensive and is easy to install. Instructions are supplied on how to install it on the roof.

A small electric motor with gearbox could be used to apply pressure to a brake pad to stop it spinning. It could operate on a the surface of the spinning section of the fan. (anon)

● That's a good idea, although we would be tempted to build a small, separate circuit running off a similarly small solar panel to control the solenoid which stops the fan from spinning.

You would need a temperature sensor too. You would need to configure it to stop the fan rotating any time the outside temperature was below a particular threshold (say, 20°C), to prevent the fan from drawing warm air out of the house in winter.

Sourcing high-voltage resistors

I wish to build the PowerUp project from the July 2003 issue (www.siliconchip.com.au/Article/3905), which specifies Phillips VR25 high-voltage resistors of 1.2MΩ. The article strongly urges that these and only these resistors should be used.

My problem is that I cannot reasonably source these. I do not have an account with element14 and in any case, their minimum order is far more than I need or want. Is there a work-around or can you tell me where I can obtain two of these resistors?

● Jaycar and Altronics don't sell those resistors but you can get them from element14 or Radio Spares. The cheaper source is RS, at http://siliconchip.com.au/l/aag4

Confusion over ceramic capacitor operation

I am building the Isolating High Voltage Probe for Oscilloscopes, described in the January 2015 issue (www.siliconchip.com.au/Article/8244). Which of the ceramic capacitors in the parts list on page 33 are AC and which are DC?

The 100nF monolithic multilayer ceramic caps do not have a voltage rating quoted. Please advise. Are multilayer ceramic capacitors the same as "monolithic"? Thank you for your help. (B. P., Tea Tree Gully, SA)

● Ceramic capacitors are not polarised so you can use them in AC or DC circuits. While the AC and DC behaviour of capacitors can vary somewhat, in general, as long as the capacitor has a sufficiently high AC and DC voltage rating for the voltages it will experience, it should be fine.

Since the total supply voltage in the circuit is only 9V, the voltage rating of the 100nF capacitors is not critical. They would typically be supplied with a rating of 50V. Monolithic and multilayer effectively is the same thing.

The only capacitors for which voltage rating is critical are those across the upper end of the input resistive divider and these are quoted at the parts list as needing ratings of 1.5kV (2 x 10pF) and 150V (1 x 100pF). Make sure those capacitors have suitable ratings.

The others can be rated for 16V DC or higher, although we've specified 50V as that is the lowest rating commonly available for those values.

GPS Tracker may not survive large supply transients

As soon as the GPS Tracker kit became available at Jaycar Werribee I purchased the kit, KC5525, based on the article in the November 2013 issue (www.siliconchip.com.au/Article/5449).

Unfortunately, towards the end of the warranty period, the MCP16301 switchmode step-down regulator chip failed and placed about 9V on its output line.

Jaycar provided me with a complete replacement kit (on the June 28th, 2014) which I subsequently built to replace the original, failed unit.

Recently, as I was motoring to Kyneton for an air-show, I detected a strange smell in the vehicle cabin. Later, I discovered that the MCP16301 had again failed, taking out the 10Ω 1W resistor.

Given that I have experienced two similar failures with IC2, I am reluctant to replace it with the same type. I have tried to find a contact for the designer but to no avail.

Could you advise me on the current requirement for the 3.3V rail as I would like to use a three-terminal linear regulator (perhaps the LM2936-3.3) instead of the SMD switchmode regulator, which is difficult to handle and thus replace.

I consider myself a competent constructor and do not believe I have made an error and certainly not the same error twice.

Generally, errors in construction cause the loss of smoke during the testing phase, not a year or three later. I appreciate whatever help you can provide. (R.S., Werribee, Vic)

- It seems as though 16V zener diode ZD1 may not be catching voltage transients which are destroying the MCP16301. We suggest that you substitute a 15V Transient Voltage Suppressor (TVS) for the zener diode. Use Jaycar Cat ZR-1175.

The failure of the 10Ω 1W resistor may have occurred before the failure of IC2 and may in fact have caused it, by allowing supply voltage spikes to be conducted directly from the automobile supply to IC2's input.

You could use a higher value, higher rated resistor such as 22Ω 5W along with the TVS, to provide more comprehensive spike protection for IC2.

We would not recommend using the linear LM2936 3.3V regulator as it will get too hot and the resulting reduction in efficiency may mean the unit does not have the time to finish saving data to the SD card before power is lost.

The cost is $5 plus GST for 50 VR25 resistors with delivery included. element14 sell 10 for $1.95 plus GST, plus around $12 per order for delivery.

Either of these suppliers will sell using a credit card. You don't need an account.

Questions about the Graphic Equaliser

Your Graphic Equaliser project featured in the June & July issues looks handy for correcting problems with difficult acoustics or cheap speakers etc, but I have a couple of questions and suggestions.

The lower two octaves are labelled 31.25 and 62.5Hz in the design and front panel, but your measurements show these controls are actually centred on about 42Hz and 70Hz. Perhaps this is a result of interaction with the coupling capacitor rolloffs and could be fixed by increasing the values of the coupling capacitors?

The decoupling and bypassing of the op amp supplies leaves a lot to be desired (as it has in most of your recent audio designs). I've never believed Douglas Self's suggestion that a single 100nF cap across the supply pins is usually adequate.

If you think about the reason for the need for bypass caps, most of the time they really need to be from each rail to ground to do any good. I've found significant improvements by adding small electros (10 or 22µF) to ground from each op amp supply pin to (a carefully routed) ground in several of your previous audio projects using op amps with only single + to - bypass caps.

A single cap across the rails might make the layout easier and more compact, but I'm convinced it isn't adequate.

The design could make a very handy room EQ for correcting room interaction (standing wave etc) problems in the bass for subwoofers or main speakers by altering the filter values so that they span the range from say 16Hz to 125Hz only. Perhaps this would be an easy and useful follow-up article? (I. B., via email)

- The octave labelling is the ideal centre frequency for each band but this may vary with component tolerances.

Our measurements show that 100nF capacitors across the supply for each op amp IC provides the required supply decoupling. Having capacitors from the positive supply to ground and negative supply to ground at the op amp could potentially introduce supply noise to the signal ground.

It is not possible on a large PCB to have capacitors decoupling the supply for the op amps that effectively decouple back to a star earth and so a capacitor across the full positive and negative supply is preferable.

You could change the capacitor values to suit the frequency range required although at the lower frequencies, the capacitors will be rather large in value and may not fit on the PCB.

Modern hifi AM radio receiver design desired

I'm currently assembling a modern design home entertainment system, based on a mixture of decent quality Chinese-sourced modules.

As I live in a rural area, I would like to incorporate a decent quality AM-band receiver into it, mainly because FM reception in my area is poor. On the other hand, night-time AM reception with a good quality receiver is excellent.

Within the magazine's archives, do you know if you have published articles covering the construction of such an AM-band radio receiver using reasonably modern technology? (R. G., Cressbrook, Qld)

- We have only described one high-quality AM tuner and that was in the February, March & April 1991 issues. It was a fully synthesised tuner with a 4-digit frequency readout. However,

Tricking a battery cooling fan to switch on

I hoping someone there can answer what I hope are a couple of simple electronics questions. I have a 2007 hybrid car and have been having overheating warning lights for the traction battery.

In particular, the OBD (on-board diagnostics) codes indicate the battery cooling fan may be reaching end-of-life. It is 10 years old with about 290,000km on the clock.

I have attached a portion of the factory wiring diagram showing the cooling fan (called "IPU module fan" – the delta winding symbol in upper right of first page).

There are four wires that feed into the fan assembly through a male-female socket connector: Red is the power source, Black is the ground and both are maybe 18G wire. The remaining two wires (Purple = NFAN & Lt Blue = FANCTRL) are much thinner wire and go directly to/from the BCM (Battery condition monitor).

I am guessing one of these sends a signal to the transistor assembly to energise the fan when the BCM detects the battery is getting hot. There are six thermistors within the battery pack that also feed into the BCM (shown elsewhere in the wiring diagram).

When driving the vehicle and the overheating light comes on, it is impossible to hear or know if the fan is operating or not. When it does operate, it is very quiet as it is located behind the back seat in a sealed steel box along with the traction battery, BCM, and other electronics.

I know it operates, at least sometimes, because after driving, with the rear seat removed and my ear at the back seat I can hear the fan and feel a breeze at the inlet duct.

I'd like to wire in a temporary manual override so I can energise the fan while driving to determine if that alleviates the overheating. So how can I do that?

What type of motor is this and what purpose do the transistors inside the fan assembly serve, to help me understand how to start the fan? From the diagram, can you advise what wiring is needed to energise the fan (a tall order I know)?

The vehicle has a normal 12V lead-acid battery for lights and accessories, so it's likely the IPU module fan operates off the 12V DC supply, however when I connect 12V DC across the red and black wires, nothing happens, ie, the fan does not start. I suspect one of the thin signal wires feeding the transistors needs to be energised as well.

The traction motor battery is nominally 160V DC supplied from NiMH batteries. Any information will be helpful and very much appreciated. Your magazine is great, keep up the good work. (P. H., Seattle, WA, USA)

● While the diagram you have sent is clearly incomplete, it is probable that the fan motor is a DC brushless type (hence the delta wiring symbol).

It will be driven by some sort of 3-phase bridge and possibly varies its speed as the battery pack gets hotter. We would assume that the transistors inside the module may provide tachometric information – but that is just a guess.

You cannot energise the fan by simply connecting external wires to it. To make the fan run, you will need to trick the controlling module (processor) into reacting to a fault condition, as in one of the thermistors going low in value (presumably the thermistors have a negative temperature coefficient of resistance).

it was based on the NECD1710g-227 microprocessor tuner controller and a Motorola AM MC13024 stereo receiver chip which would now be difficult, if not impossible to obtain. Also, the PCB design is not available.

It is possible to purchase a CQAM stereo decoder based on an MC-13028 but that seems to be the present limit of what is available online.

We have no idea how much interest there would be in an up-to-date high quality AM tuner. Interested readers may wish to let us know. Perhaps a new design could be based around a Micromite and touchscreen module.

Isolated High Voltage Probe resistor ratings

I ordered and received two sets of hard-to-get parts from you, for your Isolating High Voltage Probe project (January 2015; www.siliconchip.com.au/Article/8244).

The problem is that these resistors have the wrong power rating; 1/4W instead of 1/2W. I understand that these parts are metal film resistors. In the EPE magazine, the parts list mentioned Vishay HVR37 for these three resistors: two 620kΩ 500V 1% 1/2W and 1 x 560kΩ 500V 1% 1/2W. They are not available locally. Can you please advise. (C. Y., Singapore)

● The high-voltage resistor power specification given in the article was unnecessarily high. At the time of publication, the HVR37 resistors with 1/2W rating were readily available in the specified values.

Since then, they have become difficult to find, while 0.25W types with sufficient voltage rating and tolerance are now commonly available. Hence, this is what we have supplied.

In the article, we suggest a maximum applied voltage to the probe of 500V RMS or 1414V peak-to-peak, which works out to 707V DC peak.

Even with a higher figure of 1000V DC sustained across the input, current through the resistors is 1000V ÷ 2MΩ = 0.5mA which gives a dissipation in the 620kΩ resistors of 620kΩ × $0.5mA^2$ = 155mW. So 0.25W is a sufficient rating for these resistors (dissipation in the 560kΩ resistors is slightly lower).

We have updated the shop entry on our website to reflect the fact that purchasers may receive 0.5W or 0.25W high-voltage resistors in the pack, depending on what we have in stock.

Alternative woofer for Majestic speaker

I'm interested in using the Majestic speakers as part of a sound system for my son's rock band.

The band features a lot of keyboards so the response curves are very attractive. Is there a suitable speaker to substitute for the Etone woofer that is no longer available? (G. G., via email)

● It is a pity that you can no longer get the Etone woofer as it was a good performer. The only other woofer we

Question over Hotel Alarm efficacy

I would like to draw your attention to a nasty piece of online criticism about Publisher Leo Simpson and one of SILICON CHIP's projects, the Hotel Safe Alarm, from the June 2016 issue (www.siliconchip.com.au/Article/9954).

The criticism is that the piezo transducer will not be very loud because the project only uses a CR2032 3V lithium button cell. The critic suggests adding an inductor to make it louder. Would you care to comment? (P. V., via email)

● We would be surprised if this critic has bothered to build this project since it really is quite attention-getting, especially when it is triggered by the opening of a hotel safe door.

By the way, we have used the same driving arrangement with the Fridge Door Open Alarm from the June 2004 issue (www.siliconchip.com.au/Article/3559) and in this month's Kelvin the Cricket project.

It is particularly effective in Kelvin and there are several reasons for this.

First, the PIC12F675 drives the piezo transducer in bridge mode with anti-phase square wave signals so the effective driving voltage is close to 6V.

Second, apparent loudness is greatly increased by driving the piezo transducer in burst mode. With the specified transducer (Jaycar AB-2440 or Altronics S6140), it is surprisingly effective and has a very low battery drain when chirping.

have tried in the Majestic is the much more expensive but more rugged Celestion FTR15-4080FD.

It has a sensitivity of 97dB/W @ 1m and a power rating of 1000W! This should be available from the same vendors as the tweeter and horn, eg, Electric Factory; www.elfa.com.au

Altronics also have a 15-inch woofer you might like to consider. It has a slightly lower efficiency of 94dB/W @ 1m but much lower maximum power handling of 150W. We have not tried it.

If you do use this one, we suggest that you will need to increase the tweeter attenuation by 2-3dB (by tweaking the resistive divider) so that the sensitivities are properly matched.

Sinewave inverter project wanted

As a disgruntled electricity consumer, I fully intend to go at least partially off-grid due to rapidly rising energy costs. So I would like to ask a general question regarding projects.

Would you consider, or are you in the process of doing another high-powered 24V DC to 230VAC sinewave inverter project, suitable for solar systems, similar to the 2kW project (October 1992 – February 1993).

I built that project but had too many failures of the inverter transistors, and when these became unavailable, no longer pursued its repair.

As a personal preference, it would by necessity be a stand-alone inverter, with appropriate switching so that I would be using my own generated power when available. I don't understand how people can sell energy to a retailer via the grid at a low price and then buy back that same power at a higher price using the current metering setup.

If you're going ahead, how long before the project will appear? If not, I will go looking for a commercial product that will suit. Would you be prepared to put it to the SILICON CHIP readership to see how popular it would be? (I. T., Blacktown, NSW)

● Many people are contemplating going off the grid, as you are, but we think this could be a bit premature. Yes, the daily service charge is an irritant but at around $360 per annum it is not big enough to make going off-grid worthwhile, bearing in mind the much bigger investment you have to make.

We do not plan to design another inverter since high power sinewave units are now so much cheaper to buy. Ideally, you will need an MPPT charger feeding a battery bank of say 48V, to keep the charge and discharge currents reasonable, and then a 48V sinewave inverter. Jaycar have all the parts required to build such a system.

If you already have a grid-tied solar installation, the best way to proceed is to make sure that your smart meter is set to "net" metering whereby you are not being charged at peak rates for the energy you generate and use on-site.

This works particularly well if you have a swimming pool pump and salt-water chlorinator – your energy use is essentially free as long as the weather is good.

By the way, in NSW at least, vast numbers of people have not had their smart meters changed over to net metering.

Replacement Mosfets for Playmaster amplifier

I built the Playmaster Mosfet Stereo Amplifier published in Electronics Australia in December 1980 – February 1981 and it has served me very well.

But now I'm having a problem and it looks like the Mosfets are playing up and they are very hard to get. So are there any modern substitutes for the 2SK133 and 2SJ48? (R. H., Campbelltown, NSW)

● More modern equivalents of these lateral Mosfet devices are 2SK1058 and 2SJ162. Jaycar have discontinued these (catalog codes ZT2460 and ZT2465 respectively), however, their website says they may still have stock in some stores. We recommend you enquire at your local store and if they don't have any, see if they can get stock transferred in.

Another option is the Exicon ECF10N16 (equivalent to 2SK134) and ECF10P16 (equivalent to 2SJ49) which are available from Altronics; their catalog codes are Z1450 and Z1452 respectively. See page 320 of their latest catalog for details. This was bundled with our September 2017 issue.

According to their catalog, these parts "... whilst not direct equivalents to the Hitachi parts, will suit most circuits with only minor modifications." We suspect they will work in the Playmaster without any modifications, other than re-adjusting the bias to suit the new transistors.

Electronic relaxation aid wanted

Many years ago, *Electronics Today International* (ETI) magazine published a relaxation aid which had sensors to measure the moisture on one's finger tips.

Sorry for being so vague but can you please direct me to that article?

Digital Insulation Meter not producing correct voltages

I have completed building the Digital Insulation Meter, published in the June 2010 issue (www.siliconchip.com.au/Article/186).

The initial testing is as expected: with nothing connected to the test terminal, I = 0µA and R = 999MΩ, with every test voltage setting.

Now, when I connect my DMM (in min/max mode and manually setting the voltage range to 500V) to the test terminal and do a test, the readings vary a lot between a steady ~37V and some high peaks (~200/300V or higher).

When I keep pressing the test button, the voltage is ~37V and I can visualise the traces on the scope.

I thought my transformer was not properly wound so I did it again, paying extreme attention to wind each turn close the previous one for each of the five layers.

I used sandpaper before tinning and soldering the wire terminations. I can read 0.05Ω at the primary (between S and T) and ~2Ω on the secondary (between T and S).

I wound it with the type of wire specified in the article. I cut a piece of plastic for the insulator from the components sachets. The test results were still the same. I could reach high voltages only from time to time and am not able to sustain such values.

I think Q3 is working as expected. Apart from the transformer, I have no clue as to what would cause this inconsistent behaviour.

Any help will be greatly appreciated. A big thanks to the whole team. (O. A., France)

● Unfortunately, it isn't easy to work out the exact cause of your problems, even though you have been very helpful in sending a good description of them accompanied by a number of scope grabs.

One of these scope grabs shows the voltage at pin 5 of IC1 varying considerably but it should be constant, at 1.25V. So the fact that this voltage is varying in approximately triangular fashion is a sign that all is not well.

Since this pin is the input of the internal comparator, it also suggests that the reason why it is varying up and down is that the high voltage output at the cathode of D3 is also varying in the same way.

Frankly, we doubt if the problem is caused by your winding of T1. It seems to be a problem with IC1, which is not controlling the duty cycle of Q3 correctly in order to regulate the output voltage.

Firstly, we note that IC1 does not have a supply bypass capacitor included in the design. It is powered via the contacts of momentary switch S2, which could have a relatively high resistance. So we suggest that you solder a 470µF 16V low-ESR electrolytic capacitor between pins 6 and 4 of IC1 (+ to pin 6) and see if this helps.

Also, check that you have not swapped Q1 and Q2. It's possible that this might be the cause of the problem.

Assuming it still doesn't work, try replacing IC1.

Finally, if your unit is still not working, we would try reducing the value of the 1nF capacitor from pin 5 of IC1 to ground, as this could be destabilising the regulator feedback loop, leading to oscillation.

Perhaps SILICON CHIP or *Electronics Australia* had an article on the same topic? (D. S., Penshurst, NSW)

● We cannot recall any "relaxation aid" project in *Electronics Australia* which measured skin resistance. In fact, skin resistance measurements have been used as the basis for Lie Detectors and these purport to measure stress. This is quite the opposite of what you would want for a relaxation aid.

However, *ETI* magazine did publish a two-part article in September & October 1979 on an electromyogram which was promoted as being an aid to relaxation. In October 1989, *ETI* had a feature article on the topic of biofeedback, alpha and beta brain waves and galvanic skin resistance and they also had a project for a Galvanic Skin Resistance Meter.

Back in October 1998, SILICON CHIP published a project called a Stress-O-Meter and it monitored a person's heart rate and skin resistance and then used this data to calculate stress level which was then displayed on the PC screen. The interface to the PC was via the games port and the program was written in BASIC.

The circuit also had an audible tone output which was proportional to the skin resistance and the pulse waveform was also displayed on the PC's monitor. All the parts are still readily available apart from the PC.

GPS modules supplied may be a newer version

I purchased two VK2828U7G5LF GPS/GLONASS/GALILEO modules from your online shop on June 26. The pin labels on the modules read E-G-R-T-V-B while the data sheet for this module states they should be E-G-R-T-V-P where "P" is the 1pps output.

I cannot find any reference to a pin labelled "B" in the data sheet. Can you please clarify its function. (S. F., Carina Heights, Qld)

● Some of the VK2828U7G5LF modules our vendor have sent us have that pin labelled "P", some labelled "B".

We powered up one of the modules with the pin labelled "B" and checked the frequency on that pin. It measured 1.000Hz, so it seems that it's still a 1pps output and it's just labelled incorrectly.

The manufacturer V.KEL is based in Hong Kong/Shenzhen; some of their designers may not speak English well (or at all) so it would be easy for them to get a B and P mixed up.

Having verified that, we inspected the module closely and noticed that in the upper-left corner it was labelled "2828U8G5LF". That suggests it's a newer revision of the module.

There's little information available on the internet on the VK2828U8G5LF but what we can find suggests there aren't many differences, apart from slightly better tracking sensitivity (by 2dB) in the new revision.

We will ask the supplier to see if they have any further comments but doubt they will be able to tell us much. They probably supplied us with the newer version of the module because they ran out of stock of the older one. SC

MARKET CENTRE

Cash in your surplus gear. Advertise it here in SILICON CHIP

KIT ASSEMBLY & REPAIR

KEITH RIPPON KIT ASSEMBLY & REPAIR:
* Australia & New Zealand;
* Small production runs.
Phone Keith 0409 662 794.
keith.rippon@gmail.com

VINTAGE RADIO REPAIRS: electrical mechanical fitter with 36 years experience and extensive knowledge of valve and transistor radios. Professional and reliable repairs. All workmanship guaranteed. $10 inspection fee plus charges for parts and labour as required. Labour fees $35 p/h. Pensioner discounts available on application. Contact Alan on 0425 122 415 or email bigalradioshack@gmail.com

SERVICE/REPAIR MAN 40 YEARS – with workshop in Sydney. Available for any PC repair/build/soldering jobs, one off or many. Competitive rates. Please call Joe to discuss your requirements. Phone (02) 9698 8915.

DAVE THOMPSON (the Serviceman from SILICON CHIP) is available to help you with kit assembly, project troubleshooting, general electronics and custom design work. No job too small. Based in Christchurch, NZ but service available Australia/NZ wide. Email dave@davethompson.co.nz

FOR SALE

PCB MANUFACTURE: single to multilayer. Bare board tested. One-offs to any quantity. 48 hour service. Artwork design. Excellent prices. Check out our specials: www.ldelectronics.com.au

LEDs, BRAND NAME and generic LEDs. Heatsinks, fans, LED drivers, power supplies, LED ribbon, kits, components, hardware, EL wire. www.ledsales.com.au

tronixlabs.com.au – Australia's best value for hobbyist and enthusiast electronics from adafruit, DFRobot, Freetronics, Raspberry Pi, Genuino and more, with same-day shipping.

PCBs MADE, ONE OR MANY. Any format, hobbyists welcome. Sesame Electronics Phone 0434 781 191.
nev-sesame@outlook.com
www.sesame.com.au

WANTED

WANTED: EARLY HIFIs, AMPLIFIERS, Speakers, Turntables, Valves, Books, Quad, Leak, Pye, Lowther, Ortofon, SME, Western Electric, Altec, Marantz, McIntosh, Tannoy, Goodmans, Wharfedale, radio and wireless. Collector/Hobbyist will pay cash. (07) 5471 1062.
johnmurt@highprofile.com.au

WANTED: 6809 EXPERT WITH ANALYZER to revive a single board controller. Neither source code nor circuit available. Call John Mitchell at (02) 9417 5338 **OR** (04) 2941 7533

Master Instruments

AUSTRALIA'S BATTERY EXPERTS

Australian owned and operated manufacturer and wholesaler with strong global partnerships in the portable power industry, supplying Lithium Ion, Lithium Iron Phosphate, Nickel Metal Hydride (NiMH), SLA/VRLA and primary batteries as well as chargers, analysers, power supplies and related products in the Australian / New Zealand and Oceania region.

Our scope includes the following:
- Consumer & Retail
- Industrial Applications
- Government Agencies
- Resources Sector
- Custom Pack Builds
- Repacks & Refurbs
- Engineering Services
- Importer & Distributor

WHAT CAN MASTER INSTRUMENTS DO FOR YOU? CONTACT US

NSW: (02) 9519 1200 WA: (08) 9302 5444 VIC: (03) 9872 6422
sales@master-instruments.com.au Find us Google+

Where do you get those HARD-TO-GET PARTS?

Where possible, the SILICON CHIP On-Line Shop stocks hard-to-get project parts, along with PCBs, programmed micros, panels and all the other bits and pieces to enable you to complete your SILICON CHIP project.

SILICON CHIP ON-LINE SHOP

www.siliconchip.com.au/shop

Issues Getting Dog-Eared?

Keep your copies safe with these handy binders

Are your SILICON CHIP copies getting damaged or dog-eared just lying around in a cupboard or on a shelf?

Order online from www.siliconchip.com.au/Shop/4 or call (02) 9939 3295.

See website for overseas prices

ADVERTISING IN MARKET CENTRE

Classified Ad Rates: $32.00 for up to 20 words (punctuation not charged) plus 95 cents for each additional word. Display ads in Market Centre (minimum 2cm deep, maximum 10cm deep): $82.50 per column centimetre per insertion. All prices include GST. Closing date: 5 weeks prior to month of sale. To book, email the text to silicon@siliconchip.com.au and include your name, address & credit card details, or phone Glyn (02) 9939 3295 or 0431 792 293.

Next Month in Silicon Chip

Silicon Chip's 30th Anniversary

Silicon Chip was first published in November 1987, meaning that the November 2017 issue will be published on our 30th anniversary. The article explaining how to make the best use of our website, mentioned in this column last month, will appear in that issue (it was held over from this issue due to space constraints).

Stylish new Dipole Hifi Loudspeakers

We showed a photo of this new loudspeaker, designed by Allan Linton-Smith, in the September issue and you'll agree that it looks fantastic. Commercial dipole speakers can be frightfully expensive (up to $30,000+ a pair!) but ours can be built for a tiny fraction of that. We've also managed to overcome the bugbear of dipole loudspeakers, which is poor bass response. These are flat to 20Hz!

nRF24L01+ 2.4GHz Wireless Data Transceiver Modules

Jim Rowe describes the operation of these 2Mbps digital radio modules with software that lets you communicate with a pair of Arduino or Micromite modules.

New AM radio receiver to build

AM Radio still has a lot of advantages and here's an AM Radio receiver that you'll have a lot of fun building, you'll learn a lot about the how, when, where and why of AM radio – and end up with a radio that works well and looks great on your bedside table, shelf... anywhere! No hard-to-solder bits, either: it's all discrete components and is all built on one PCB – tuning dial and loudspeaker included.

Note: these features are prepared or are in preparation for publication and barring unforeseen circumstances, will be in the next issue.

The November 2017 issue is due on sale in newsagents by Thursday, October 26th. Expect postal delivery of subscription copies in Australia between October 26th and November 14th.

Advertising Index

Altronics ..... FLYER
Dave Thompson 103
Digi-Key Electronics 3
Emona Instruments ..... IBC
Hare & Forbes 35
High Profile Communications 103
Jaycar IFC,49-56
Keith Rippon Kit Assembly 103
LD Electronics 103
LEDsales 103
Master Instruments 103
Microchip Technology ..... OBC
Mouser Electronics 7
Ocean Controls 9
Sesame Electronics 103
SC Online Shop 75,94-95
SC Radio, TV & Hobbies DVD 85
Silicon Chip Subscriptions 87
Silicon Chip Wallchart 57
Tronixlabs 103
Vintage Radio Repairs 103

Notes & Errata

Automatic NBN/ADSL Router Rebooter, September 2017: as depicted in the circuit on page 36, the relay is incorrectly shown with the normally-open contacts in series with the router. The circuit should be changed to show the normally-closed contacts in series with the router. That will mean that when the relay is enabled, the power to the router will be interrupted.

Power Supply for Battery-Operated Valve Radios, August 2017: the case specified in the text is too large. It should be PacTec LH55-130. The short link has been updated to go to the correct Mouser catalog item (616-71886-510-000). Also, note that if you use the B battery sockets on the rear panel you need to make sure they are not swapped or the power supply will be shorted out.

Vintage Radio (DKE38), July 2017: in the middle column of page 94, the article states that "The amplified signal is developed across the 2MΩ resistor R3...". This is incorrect. R3 is a feedback resistor from the loudspeaker. The demodulated audio appears across 200kΩ resistor R2.

WARNING!

Silicon Chip magazine regularly describes projects which employ a mains power supply or produce high voltage. All such projects should be considered dangerous or even lethal if not used safely.

Readers are warned that high voltage wiring should be carried out according to the instructions in the articles. When working on these projects use extreme care to ensure that you do not accidentally come into contact with mains AC voltages or high voltage DC. If you are not confident about working with projects employing mains voltages or other high voltages, you are advised not to attempt work on them. Silicon Chip Publications Pty Ltd disclaims any liability for damages should anyone be killed or injured while working on a project or circuit described in any issue of Silicon Chip magazine.

Devices or circuits described in Silicon Chip may be covered by patents. Silicon Chip disclaims any liability for the infringement of such patents by the manufacturing or selling of any such equipment. Silicon Chip also disclaims any liability for projects which are used in such a way as to infringe relevant government regulations and by-laws.

Advertisers are warned that they are responsible for the content of all advertisements and that they must conform to the Competition & Consumer Act 2010 or as subsequently amended and to any governmental regulations which are applicable.

"Rigol Offer Australia's Best Value Test Instruments"

Oscilloscopes

RIGOL DS-1000E Series

- 50MHz & 100MHz, 2 Ch
- 1GS/s Real Time Sampling
- USB Device, USB Host & PictBridge

FROM $469 ex GST

NEW RIGOL DS-1000Z Series

- 50MHz, 70MHz & 100MHz, 4 Ch
- 1GS/s Real Time Sampling
- 12Mpts Standard Memory Depth

FROM $579 ex GST

RIGOL DS-2000A Series

- 70MHz, 100MHz & 200MHz, 2 Ch
- 2GS/s Real Time Sampling
- 14Mpts Standard Memory Depth

FROM $1,247 ex GST

Function/Arbitrary Function Generators

RIGOL DG-1022

- 20MHz Maximum Output Frequency
- 2 Output Channels
- USB Device & USB Host

ONLY $539 ex GST

NEW RIGOL DG-1000Z Series

- 30MHz & 60MHz
- 2 Output Channels
- 160 In-Built Waveforms

FROM $971 ex GST

RIGOL DG-4000 Series

- 60MHz, 100MHz & 160MHz
- 2 Output Channels
- Large 7 inch Display

FROM $1,313 ex GST

Spectrum Analysers

RIGOL DSA-800 Series

- 9kHz to 1.5GHz, 3.2GHz & 7.5GHz
- RBW settable down to 10 Hz
- Optional Tracking Generator

FROM $1,869 ex GST

Power Supply

RIGOL DP-832

- Triple Output 30V/3A & 5V/3A
- Large 3.5 inch TFT Display
- USB Device, USB Host, LAN & RS232

ONLY $649 ex GST

Multimeter

RIGOL DM-3058E

- 5 1/2 Digit
- 9 Functions
- USB & RS232

ONLY $673 ex GST

Buy on-line at www.emona.com.au/rigol

Sydney
Tel 02 9519 3933
Fax 02 9550 1378

Melbourne
Tel 03 9889 0427
Fax 03 9889 0715

Brisbane
Tel 07 3392 7170
Fax 07 3848 9046

Adelaide
Tel 08 8363 5733
Fax 08 83635799

Perth
Tel 08 9361 4200
Fax 08 9361 4300

EMONA

email testinst@emona.com.au

web www.emona.com.au

Simplify Your Low-Power LCD Designs

MCUs That Do More

Simplify the design of your low-power Liquid Crystal Display (LCD) devices. The PIC16(L)F19197 family of 8-bit microcontrollers gives you the ability to drive up to 360 LCD segments while incorporating battery-friendly features. Thanks to the integrated charge pump, these MCUs are capable of driving 5V LCD displays while being powered at 3.3V. They also feature a 12-bit ADC with Computation (ADC²), which automates sensor interface functions that previously required software routines. The wide range of pin count and memory options ensure a perfect fit for your next LCD design.

Key Features

- Up to 56 KB Flash program memory and 4 KB RAM
- 12-bit ADC², up to 44 channels
- Integrated LCD control for up to 360 segments
- Available in 28 to 64 pins
- Easy setup with MPLAB® Code Configurator (MCC)

Contact Information
Microchip Technology Australia
Email: aust_nz.inquiry@microchip.com
Phone: +61 (2) 9868-6733

www.microchip.com/8bitLCD

microchip DIRECT
www.microchipdirect.com

MICROCHIP

The Microchip name and logo, the Microchip logo and MPLAB are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries. All other trademarks are the property of their registered owners. © 2017 Microchip Technology Inc. All rights reserved.